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The Eighty-Third Meeting of the American Astronomical Society

By C. M. HUFFER

Each meeting of the American Astronomical Society seems to be characterized by some outstanding feature. There were several such features at the Bloomington meeting which was held June 18-21, 1950. The long program of papers, the nearly continuous rain (which stopped, however, when we wanted nice weather for a picnic), the fine dormitory where we were housed, the visit and picnic at the Link Observatory, and the recital which was arranged for the special benefit of the Secretary, but was enjoyed by several hundred people, were all outstanding.

The astronomers from far and wide began to gather on Sunday afternoon at the Men's Quadrangle of the University of Indiana. The host, Frank Edmondson, his family, and many assistants were on hand to help us find our way in the complicated dormitory, which must be one of the finest on any campus. The rooms were plainly but comfortably furnished and we enjoyed the convenience of a snack bar and very comfortable lounges, not only in the central part of the building but also scattered in various parts of the building. The management must have forgotten that the Council was composed of "nine old men" because it was assigned a pent-house lounge on the roof which was accessible only by climbing the stairs. It was one of the most-used rooms in the building. It is doubtful if the astronomers occupied their rooms for as long periods as the Council did its pent-house (at least it did not seem as long). The total length of the Council meetings was ten hours.

Those of us who came from the North experienced a decided change in temperature—from 37° F. in Wisconsin to 80° F. or more in Bloomington with very high humidity. We had driven most of Sunday through the rain and arrived in a hot, humid, drenched Bloomington late in the afternoon. The night also produced a thunderstorm and the rain continued intermittently during parts of the remaining days.

The social events began with an open-house at the Kirkwood Observatory on the first evening. This open-house was only hearsay to the members of the Council so we shall have to omit a description. The Secretary was also unable to attend the reception at the home of President Wells of the University on Monday evening. The first of these two events was terminated by a thunderstorm.

The scientific part of the meeting began at 9 A.M. Monday morning

after a brief speech of welcome by Dean Ashton of the University. Then President Joy called on Dr. Stebbins to take the chair. He began the contributed papers by calling on Dr. Struve for his paper on three spectroscopic binaries. The meeting place was the lecture room of the Business and Economics building. Fifty-seven papers were listed on the program, the subjects ranging through the various divisions of astronomy—from the planets, through observations of individual stars, to a proposed model of the universe.

Tuesday was the most unusual day of the meeting. It started in the morning with a series of three papers which had been arranged in partial celebration of the 50th anniversary of the founding of the Kirkwood Observatory. The three participants were Dr. Dirk Brouwer of Yale University, Dr. Gerard P. Kuiper of the Yerkes Observatory, and Dr. Paul Herget of the University of Cincinnati. A fourth member of the group, Professor L. E. Cunningham of the University of California, was unable to be present and his paper was read by title. The topics dealt with the minor planets in memory of Professor Kirkwood, the discoverer of the Kirkwood gaps in the system of the minor planets and in the ring system of Saturn.

Next in order was the trip to the Link Observatory, about 35 miles north of Bloomington. The trip was made in private cars and the route took us through a lovely part of south-central Indiana. Arriving at the Observatory about noon, all members of the party—about 180 in all—inspected the telescopes of the Observatory which had been given to the University of Indiana by Dr. Goethe Link, who had erected a fine 36-inch Newtonian reflector on the grounds of his summer home. This telescope is now used mainly for photoelectric observations. There is also a small photographic refractor for the asteroid program of the department. Then followed a picnic lunch served in a large tent which had been erected in case of rain. As noted above, the rain fortunately stopped, but the tent was a welcome protection from the wet grass of the hay field in which it had been placed. Excitement was stirred up by a telephone call for the Treasurer and Secretary from Washington. Everybody thought it was from the FBI and suspense remained high because the Treasurer was in Bloomington and could not be reached until four o'clock. However, it was not the FBI but the National Research Council which was asking for information.

Returning to Bloomington, the next items of business were the meetings of the Executive Committee and Commission Chairmen of the USA Section of the IAU. These sessions were to inform the members of the IAU commissions and those who hope to go to the IAU meeting in Leningrad next year about the possibilities of obtaining transportation, passports, and financial assistance. The first two look hopeful, but the last almost hopeless. The meetings adjourned in time to permit all to attend the recital in the University auditorium.

The program was in three parts: organ, tenor voice, and piano. Pro-

fessor Ragatz announced and described his selections, then played them on a four-manual organ. The tenor songs were sung by another Professor of Music, Myron Taylor, accompanied on the piano by his wife. Some were serious, some in lighter mood; all were enjoyable. The third and final part of the recital consisted of three improvisations on the piano by Professor Fuleihan. The first was based on a theme of five notes—E flat, F sharp, G, d, h,—called out at random from the audience. This unusual theme was developed into an interesting one-movement sonata.

At the annual meeting on Wednesday, June 21, the following named persons were elected as officers.

Vice-president: C. S. Beals, Ottawa, Canada
Secretary: C. M. Huffer, Madison, Wisconsin
Treasurer: J. J. Nassau, East Cleveland, Ohio
Representative, National Research Council: J. J. Nassau, East Cleveland, Ohio
Councilors: A. E. Whitford, Madison, Wisconsin
R. J. Trumpler, Berkeley, California
P. C. Keenan, Delaware, Ohio

The Secretary announced the loss by death of three members of the Society: Professor H. M. Goodwin, Dr. W. J. Humphreys, and Mr. J. Madison Showalter.

Seventeen new members of the Society were elected. They are:

Mr. Halton C. Arp, California Institute of Technology, Pasadena 4, Calif.
Mr. Robert C. Cameron, Astronomy Dept., Indiana University, Bloomington, Ind.
Mr. Joseph W. Chamberlain, Observatory, University of Michigan, Ann Arbor, Mich.
Mr. John H. DeWitt, Jr., Radio Station WSM, Nashville, Tenn.
Mr. Ray T. Dufford, Missouri Valley College, Marshall, Mo.
Mr. Douglas Duke, Yerkes Observatory, Williams Bay, Wis.
Mr. Paul Engle, Dept. of Physics, New Mexico State College, Las Cruces, N. M.
Mr. Robert H. Hardie, Yerkes Observatory, Williams Bay, Wis.
Prof. Eberhard Hopf, Mathematics Department, Indiana University, Bloomington, Ind.
Mr. Karl Otto Kiepenheuer, Yerkes Observatory, Williams Bay, Wis.
Prof. Brian H. Mason, Geology Dept., Indiana University, Bloomington, Ind.
Mr. W. S. McClenahan, Dominion Observatory, Ottawa, Canada.
Mr. William C. Miller, Mt. Wilson Observatory, Pasadena, Calif.
Mr. William H. Potter, Astronomy Dept., Indiana University, Bloomington, Ind.
Dr. Eugene Rabe, 3442 Oak View Place, Cincinnati 9, Ohio.
Dr. Hans Roth, Sproul Observatory, Swarthmore, Pa.
Mr. George F. Siddons, Electronics Shop, Indiana University, Bloomington, Ind.

The meeting concluded with a special dinner in Alumni Hall of the Indiana Union. After dinner the Annie J. Canon prize was presented to Mrs. Helen Sawyer Hogg by President Joy. Mrs. Hogg made an appropriate speech in accepting the prize. Next, President Joy announced the election of Dr. Goethe Link, donor of the Link Observatory to the University of Indiana, as a patron of the Society. Mr.

Charles Federer spoke about the Centennial of the first astronomical photograph, inviting those in the region of Cambridge to attend a celebration on July 17 at which an attempt will be made to repeat the first daguerreotype of the star Vega one hundred years before. He also invited those present to attend a meeting of the Astronomical League to be held at Wellesley College in early July. The final speaker was Professor Bertil Lindblad from Sweden, who is President of the International Astronomical Union. Professor Lindblad spoke on the subject of International Coöperation in Astronomy. The evening program ended by a showing of colored slides of a flight to South Africa and of the South African observatories in Johannesburg taken by Professor John Irwin of the Indiana Department of Astronomy.

The following resolution of thanks was read by Dr. Lyman Spitzer, Jr.:

> When the Council conferred upon me the great honour of recording the thanks of the American Astronomical Society for the hospitality showered upon us at our 83rd meeting, I was appalled by the magnitude of this responsibility. For many meetings a routine note of appreciation is adequate. But for meetings such as this, where our every need is anticipated and provided for, a really extraordinary message of thanks seems appropriate.
>
> So I have racked my brains for an adequate medium to express our gratitude to Indiana University and the Kirkwood Observatory for their careful planning, their faultless arrangement of each detail of our meeting. First, I attempted a poem, in rhymed couplets, praising the Men's Quadrangle, probably the most gorgeous and certainly the newest edifice in which our Society has ever been housed. The spotless cleanliness of our rooms led me to include the lines from last night's song,
>
> "They had washed them in permanganate with carbolated soap."
>
> But I couldn't see that our meetings had in any sense been "as cold as vanished hope," so I dropped this line of attack.
>
> Next, I turned to the Reception by President Wells, our gracious and charming host. The delectable scoops of ice cream,—I should hate to confess how many I personally disposed of,—and other delicious refreshments led me to try a little song along the lines of Gilbert and Sullivan.
>
> "I am the very model of a modern college president,
> I serve to all astronomers delectable refreshiment."
>
> But the effort got all tangled up with collisions of galaxies and publication costs, and, alas, had to be abandoned.
>
> The picnic at Link Observatory certainly deserved a special effort. For this high point of our meeting, where Director Edmondson was even able to arrange appropriate weather, first cool for variety, then warm, and where a lavish offering of food and Dr.

Link's lovely flowers set off a delightful occasion to renew old acquaintances and find out what was really in those papers our friends had written, for this high point nothing less than a sonnet would do. So last night, after the third Council Meeting, I retired to my room for this *magnum opus*. But the deliberations of Commissions 43 and 44, meeting in full plenary session outside my window, made concentration impossible, and this effort, too, came to naught.

The concert, with its magnificent organ music, its rich tenor songs, and its incredibly ingenious improvisations deserved special thanks. I thought of asking Dr. Wrubel, a pianist of distinction, and a member-to-be of the Kirkwood Observatory staff, to compose a special cantata for the occasion, "Nun müssen wir alle Herrn Edmondson danken." But the curve of growth of this cantata was too slow, and there are no results to report along this line.

And so I am forced to abandon my attempts and I conclude that no really adequate expression of our appreciation for so successful a meeting is really possible. And so, I say, simply to our hosts,

It has been a wonderful meeting;
We hope we can return to this delightful spot soon again.

Technically, the symposium and dedication of the new observatory at the University of Michigan was not a part of the meeting of the American Astronomical Society. However, at the request of the director, Dr. Goldberg, the invitation to attend the Ann Arbor meeting was sent to all members of the Society through the office of the Secretary. Since all participants in the symposium are members of the Society, the symposium was an integral part of the summer meeting of the Society. Immediately after the close of the meeting in Bloomington a large number of astronomers drove from Bloomington to Ann Arbor for the opening session on Thursday evening, June 22.

We were housed in a large dormitory for girls on the campus of the University of Michigan and meals were provided in the dining room in the basement. The only social event was a reception in the dormitory parlors on Friday evening.

The first session was held in the Lydia Mendelssohn Theatre and consisted of a lecture by Dr. Walter Baade of the Mount Wilson and Palomar Observatories entitled "Relations Between the Composition and Structure of Galaxies." Dr. Baade's lecture was illustrated by slides showing new results obtained with the 200-inch telescope.

The lecture was continued on Friday morning in the Public Health Auditorium on the campus as the first of eleven invited papers of a symposium entitled "The Structure of the Galaxy." The symposium speakers, in addition to Dr. Baade, were as follows: Nicholas U. Mayall, Lick Observatory; W. W. Morgan, Yerkes Observatory; J. J. Nassau and Sidney W. McCuskey, Warner and Swasey Observatory; R. Minkowski, Mount Wilson and Palomar Observatories; Bertil Lindblad,

Stockholm Observatory; A. N. Vyssotsky, Leander McCormick Observatory; Freeman D. Miller and Karl G. Henize, University of Michigan Observatory; Harlow Shapley, Harvard College Observatory. These papers described the recent studies of the galaxy, the Andromeda Nebula, and the Magellanic Clouds by the various observatories. Since the papers will be published in full by the University of Michigan, no attempt is made to describe them here.

On Saturday morning the formal dedication of the new Heber Doust Curtis Memorial Telescope was held in the Lydia Mendelssohn Theatre. On the platform was a small model of the new observatory. Dr. Goldberg, director of the Michigan Observatories, presided and called on President Alexander G. Ruthven, President of the University, Mr. Kenneth L. Moore, member of the McGregor Fund Committee, and Dr. Joel Stebbins of the Lick Observatory and Director Emeritus of the Washburn Observatory. Dr. Stebbins, a personal friend of Dr. Curtis for 40 years, spoke of his life and work and ended with the following quotation from Curtis's writings:

"But whatever our viewpoint, the influence of astronomical knowledge is certainly toward an exaltation of soul. Whatever our place and purpose in this universe, whatever may be our school or belief, all modern thought has been tempered, changed, and enriched through the knowledge that we are all members of an organization so wonderful, so unthinkable great, that we can not go far wrong in applying to it the adjective divine."

On Saturday afternoon and Sunday those who had remained after the end of the dedication ceremonies visited the new observatory and also the McMath-Hulbert Observatory at Lake Angelus. All agreed that the symposium was among the best that had ever been held. It was certainly up-to-date and presented new data and conclusions about the structure of the galactic system and its companions, the Andromeda Nebula and the Magellanic Clouds.

WASHBURN OBSERVATORY, MADISON, WISCONSIN.

A Short History of the Lick Observatory*

By F. J. NEUBAUER

PART II

In the second part of this Short History of the Lick Observatory, the emphasis is laid chiefly upon the first ten years of the Observatory's existence under the directorship of E. S. Holden. The scientific achievements and the success of the original staff are dealt with only insofar as they touch the personal side of the one staff member or another. The scientific results have been well told in the ten or eleven editions of

*Continued from May (1950), page 222.

the *Brief Account of the Lick Observatory* and need not to be retold here. These Accounts have appeared since 1894 at more or less regular intervals.

It is of interest to know something about these men, pioneers in the true sense of the word, and to know also something of their activities here on Mount Hamilton. The last member of the original staff died in 1924, and this is long enough ago to speak of their lives as history. Since it is due to them that the Lick Observatory gained within a few years an international reputation, they deserve to have their names remembered.

Edward Singleton Holden

To some extent this history is the history of 25 years of Holden's life. His planning for the fourteen years previous to his directorship made the Observatory a success. He was also the creator of the Astronomical Society of the Pacific which has flourished now for 62 years. There are three or four men alive now who were appointed later in his career to the Lick staff who know from their experience of the life on the mountain in the nineties of last century. Although they are retired from active work, much information was gained from them. But most of this Short History is based upon the enormous correspondence of Holden's time, contemporary newspaper clippings, and records to be found in the library of the Society of California Pioneers in San Francisco. Holden's correspondence consists of approximately 5000 letters in many volumes and all in his own bold and clear handwriting.

For reasons unknown now to us, and for that matter unknown to most everyone of his own days, Holden was not a popular administrator, and he became more and more unpopular as time went on. This is of little importance now. The fact remains and will remain as long as the Lick Observatory exists, he was a successful director. Frequently the statement has been made, as long as sixty years ago and even in more recent time, that Holden was not an astronomer, and by that evidently is meant he was not the type of the highly trained specialist our universities now turn out. Viewed from an objective standpoint, this statement is only partially true. Although not outstanding in any particular field of astronomical investigation, he fostered the science in general, at a time when astronomy needed a man with Holden's gifts. Better and larger telescopes were coming into existence in the United States, the people were becoming astronomically minded. Holden was the man who could give the information everyone wanted. Holden wrote much and wrote well of astronomical topics, and this service was part of the foundation upon which the astronomical science developed so successfully in the United States, and, indeed, everywhere else. One of the severe critics of Holden's astronomical work in his own time made the statement that any good newspaper reporter with access to a good library could write just as well. All of this is so, provided the

reporter had time to delve into an astronomical library and perhaps take off two or three years from his regular work to study astronomy.

One thing all agreed upon was that Holden was a born librarian. He had an extraordinary talent for classifying and cataloguing books and, for that matter, everything else from stars to coin of the various realms. This characteristic was part of his habit of painful orderliness and neatness which no modern system of filing can surpass. He was gifted with a detailed and rententive memory for all he ever heard, read, or saw. He would have been an outstanding success had he been the head of a large library, such as the Library of Congress.

He was a first-class publicist, writing much for the larger papers and better magazines, and was always willing to supply them with readable articles. He could and would write upon most any topic. To illustrate his versatility, it is best to give a few titles of his memoirs, essays, and general articles which appeared in the press. He wrote on the "Bastion System of Fortification," "The Cipher Dispatches used in the United States and Elsewhere," and "Treatment of Pamphlets in Special Libraries." Then he wrote books like the "Picture Writings of Central America," "The Mogul Emperors of Hindustan," memorials about W. C. and C. P. Bond, books about Herschel's writings, and Herschel's family. Then he published several catalogues of stars, catalogues of earthquakes, catalogues of insects. There were several smaller volumes for popular consumption like "Earth and Sky," "Elementary Astronomy," "Family of Sun," "Essays on Astronomers," "Stories of Great Astronomers," and "The Sciences." He also wrote patriotic essays like "Our Country's Flag" and several others of similar tenor. Then he published "A Primer of Heraldry," "About Real Things in Nature," and the best remembered "The Centennial History of the U. S. Military Academy." There are several children's books to his credit, and some critical discussion of oriental and Arabic poetry. To be sure there never was another astronomer like Holden. One astronomer of the past made the statement "Holden writes a whole book in the time it takes me to write a letter to my family."

When Holden assumed the directorship of the Lick Observatory, he had the full backing of the Regents of the University of California and the goodwill of all the citizens of the State. The Californians were very proud of "their" Observatory. Holden's name became familiar to everyone due to the enormous publicity the Observatory received during the construction period from the press and magazine articles, to say nothing of the numerous pamphlets by professional lecturers. Illustrations of the various buildings going up, portraits of Holden, and the plan of the large telescope became familiar to all. Geographies for grade school included pictures of the telescopes and of Holden. So Holden had a great reputation before he had time to make one himself as an astronomer. To live up to all this publicity would have been a task for anyone, Holden included. He was a much harrassed man and could not

take refuge in a nervous breakdown or ulcers, since such things were unknown in a pioneer society in which he was placed.

The Regents gave him free choice in practically everything pertaining to the Observatory. He selected his own staff of astronomers, a remarkable set of men. He had great organizing ability and a military manner. He was austere, very formal in the execution of the smallest matter, and always serious. Instructions to his staff and workmen were always in writing in terse short sentences all ended "by order of the Director," a phrase which annoyed some of the early staff.

In order to introduce the original staff it is best to give a short biographical sketch of each member, and here is first of all the Director, Edward Singleton Holden. Holden was born in St. Louis, Missouri, on November 5, 1846. From 1860 to 1862 he was in a private school in Cambridge, Massachusetts. While there he frequently visited the G. P. Bond family. Mrs. Bond was a cousin of Holden and G. P. Bond was the Director of the Harvard College Observatory. These frequent visits aroused in him, according to his own statement, "a boundless admiration for the science to which the Bonds, father and son, devoted their life." He returned to St. Louis to enter Washington University from which he graduated in 1866. For some time during his four years there he was a member of the household of Professor Chauvenet, professor of mathematics at the University. After graduation he entered the U. S. Military Academy at West Point. In 1870 he was a Second Lieutenant serving as instructor in the Academy, teaching natural sciences. He resigned from the Army in 1873 to accept a position as professor in the U. S. Navy, serving as astronomer at the U. S. Naval Observatory. He was first an assistant with the meridian circle, later assistant with the new 26-inch refractor under Simon Newcomb. After one year, that is in 1874, Newcomb recommended Holden to D. O. Mills, the President of the First Lick Trust, as a possible future director for the planned Lick Observatory. Since Holden was not yet 28 years old, and had only one year of practical experience in observatory work, this speaks volumes for the good opinion Newcomb had of Holden.

While Holden was at the U. S. Naval Observatory, he familiarized himself very thoroughly with the astronomical literature in the Observatory library, the best then in existence in the United States. He took a great interest in the reorganization of this library in a way which was admired by all the staff. In fact, he was placed in charge of the library and relieved from all other observatory duties. This was about 1878 or 1879 and it was then that his writings began to appear quite frequently. In 1876 the Navy sent him to England as a U. S. Agent to examine and report upon the South Kensington Loan Collection of Scientific Instruments with instructions to pay special attention to the improvements in geodetic and astronomical instruments.

While in London Holden met Captain Floyd for the first time. Floyd had come over about business in connection with the proposed Lick Tele-

scope. Floyd invited Holden to travel with him for a few weeks to visit glassworks and lensmakers, and study the mountings of European telescopes. Both men were young and full of enthusiasm for the project in hand. They established a friendship which lasted for many years. Whether Floyd then asked Holden to be an advisor to the Lick Trust cannot be shown by any records, but evidently something of that kind must have been agreed upon, for from that time on Holden worked on plans for the future Lick Observatory. These plans are remarkably like the final ones adopted by the Trust in 1879.

When Holden returned to the United States and made his report about the London Exhibition, the report received many flattering comments by scientists and by his colleagues in the U. S. Naval Observatory. He was considered a coming man in his field, and was offered various important positions in American observatories and universities.

Holden resigned from the U. S. Naval Observatory in 1881 to accept the directorship of the Washburn Observatory of the University of Wisconsin. There was no question in the mind of those who knew that this step was a preparatory one toward the future directorship of the Lick Observatory which, by now, was actually under construction. In 1883 he was put in charge of the solar eclipse expedition, a joint expedition by the American Academy of Sciences and the U. S. Naval Observatory. The eclipse was observed on May 6, 1883, from the Caroline Islands in the Pacific Ocean. The expedition was successful and Holden's report was printed in Volume 2 of the "Memoirs of the National Academy of Sciences." For neatness, clearness, and completeness, this report is still worth reading.

At their meeting on October 20, 1885, the Regents of the University of California appointed Holden President of the University of California with the understanding that he was to assume the directorship when the Lick Trust should turn the Lick Observatory over to the University. His service as president began on January 1, 1886, and as director of the Lick Observatory on June 1, 1888. His term as president was uneventful which is perhaps the best sign of his success as president. In those days of so much external and internal politics in state institutions, the presidency of any State University was a difficult position to occupy. During his presidency the completion of the Lick Observatory was always foremost with him and the Lick Trust and the Regents felt they now had the man they needed close at hand.

At a Regents' meeting on January 10, 1888, the first astronomical staff was appointed upon the recommendation of Holden and it consisted of the following men:

E. S. Holden,	Director and Astronomer
S. W. Burnham	Astronomer
J. M. Schaeberle	Astronomer
J. E. Keeler	Astronomer
E. E. Barnard	Astronomer

C. B. Hill, Assistant Astronomer, Secretary, Librarian
John McDonald, Machinist, Foreman
One janitor and one laborer

The appointments dated from the day the Lick Observatory was accepted formally by the Regents, actually June 1, 1888.

At the same meeting, *Articles on the Government of the Lick Observatory* were adopted, 13 in all, which have been more or less followed since. These articles evidently came from the pen of Holden and only one or two need to be pointed out here. Article number eight is of interest. Holden always wished to have a graduate school of astronomy of high standing established in the University. This article created such a school with the Lick Observatory as part of the scheme. Graduate students were to be admitted for residence at the Observatory and to become candidates for higher degrees. Another article which might be of interest was number six. It defines the power of the director and one of its paragraphs states: "No communications to journals purporting to emanate from the Lick Observatory, or relating to the work of the Lick Observatory are to be made by officers or employees without the formal approval of the Director." This article later caused some unpleasant press comments, however no one would question the common sense of this rule nowadays. But, in those days of rough individualism, the sensitiveness of the pioneer must be taken into consideration.

The Regents and the members of the Lick Trust held a joint meeting on May 8, 1888. The Trust gave an account of the financial standing of the accounts of the Lick Observatory which was to be turned over formally to the Regents on June 1, 1888. The Trust had the following statement to show:

Amount expended on the bequest buildings, instruments, etc.	$577,242.26
Amount (Cash) to be turned over to the Regents .	90,000.00
Contracts and bills acknowledged to be correct and unpaid	12,081.04
Bill presented by Professor Holden for advice, etc., to the Lick Trustees which is disallowed by the Trustees	6,000.00

The statement continues: "This disallowed liability of $6,000.00 claimed by Professor Holden must remain in abeyance until legally or otherwise adjusted."

The last item was the beginning of Holden's troublesome years ahead. Newspapers took it up at once and spread it all over the State and the nation. Glaring headlines such as "High Priced Stargazer Meets With Well Deserved Rebuff" were followed by many unkind names and remarks. Holden, whose name was News just a few days before became the subject of continuous newspaper attacks for the next ten years. These attacks were unjust in many cases. Few can understand now or

even understood then how just one man could gradually gather as much dislike as Holden did during the next ten years. Park of it was, no doubt, his fault. He would air his defense and his personal views in open letters to the press. Sometimes one letter was 500 words long. The Lick Trustees felt that it was due to their influence that Holden had been appointed President of the University at a high salary and that, as President, the services he rendered for the Lick Observatory were part of his job, just like the advice he was expected to give to any other department of the University. Moreover, one or two of the Trustees were afraid that bills similar to Holden's would be rendered to them if Holden's bill were allowed. Many astronomers in the United States and abroad were consulted during the construction period and their advice was freely given. Incidentally, this is about the only time the newspapers were on the side of the Lick Trustees. This Trust was always the pet object of attack of the papers in San Francisco which were followed by the papers in the smaller communities. For years, the "Daily Tirade" was a California household word for the newspaper attacks upon the Lick Trust. From now on Holden became the target of this tirade. His mistake was to present his bill at that joint meeting. Had he done it earlier while the Trust was still in full charge, a settlement would perhaps have been made. The publicity killed the bill finally but not until it was discussed in the State Legislature, although it never reached the floor there. Another error committed by Holden was to write an open letter to several newspapers asking them to withhold judgment about this matter until final settlement. This letter was too dignified for the reporters and they again had a glorious time criticizing Holden. In a few papers, the bill became $12,000.00. It must have been from one of these erroneous newspaper reports that the great Simon Newcomb got his figures. In his book "Reminiscences of an Astronomer," page 193, there appears the statement ". . . to file an astounding claim for the sum of $12,000.00 on account of services rendered, etc., etc.". Newcomb's book appeared some five years after Holden left the Lick Observatory, and though Holden was living, he had evidently lost his old fighting spirit and did not correct Newcomb's statement. To all this sad episode one can only say, Holden was unjustly attacked by the press and he had no friends to defend him. The sum of $6,000.00 for services rendered over a period of fourteen years could have been considered not too much even in those days. It certainly compares modestly with professional fees in some other lines of advice. Holden's advice given to the Trustees was good; the existence of the Lick Observatory is the best proof of this. Captain Floyd could not have built the Observatory without Holden's enthusiastic advice and Holden was lucky to have in Captain Floyd a man who could quickly see the advantages and defects of the plans submitted. These two men worked well together but it was Floyd who made Holden's dream come true.

Holden could not refrain from airing his views in public letters. Unfortunately, this only fired the antagonism of the press and created conditions that in the end made Holden give up his position and leave the State of California, never to return. There are many things to be said in favor of Holden and not the least is the fact that he was not forced to resign from the Lick Observatory, for the Regents stood by him until he left the Mountain.

For a few years he lived in Washington and New York as a free lance writer and from 1901 on he was the librarian of the U. S. Military Academy at West Point from which institution he had departed 30 years before to start his astronomical career. He died at West Point on March 16, 1914. His wife was Mary Chauvenet, daughter of Professor Chauvenet of St. Louis, whom he married in 1871. He left one son living now in Massachusetts. This was Edward C. Holden, known as "Ned" to the mountain community when he attended school in San Jose in the nineties.

As an astronomer, Holden was chiefly a self-trained man, but for that matter so was almost everyone who followed a profession. Postgraduate schools were just being organized in the eighties or nineties. Most professional training was begun with the freshman years in college. Even the University of California Schools of Medicine, Law, and Engineering required only high school preparation. Only a few graduate schools in the East offered advanced courses or higher degrees. West Point turned out the engineers the country needed. Many West Point and Annapolis graduates became professors in the various state universities then in their infancy. The Coast and Geodetic Survey was the practical school for those young men who were astronomically inclined. So-called "New Astronomy" was just coming in. It later became known as "astrophysics" and now dominates the astronomical field of investigation.

During Holden's college years astronomy, as taught in school, was an adjunct to the teaching of mathematics. A few graduates of colleges went for a year or two to Europe to pursue their studies in the older universities and on returning to their own country became professional astronomers. These became the founders of Astronomy which a sarcastic European professor called "Astronomy, die Amerikanische Wissenschaft."

Thus, the original staff of the Lick Observatory were all self-trained astronomers with one exception, James H. Keeler, who spent a year or so in Germany where he studied spectroscopy.

Sherburne W. Burnham

The staff consisted of relatively young men. Burnham was the oldest and he was fifty years old when he came to the Lick Observatory as astronomer on June 1, 1888. Holden was 42, Schaeberle 35, and Keeler and Barnard both in the 31st year. Burnham had acquired an

international reputation as a double-star astronomer years before he came to the Lick Observatory. During the seventies and eighties he was the court reporter in the United States Circuit Court, in Chicago, Judge Drummond presiding. It is told that one day in the early eighties during a discussion among the attorneys, the name of Burnham, the famous Chicago astronomer was mentioned, but no one there in that group associated Burnham, the astronomer, with their own Burnham, the court reporter, and this casual incident tells as much of Burnham's character as a lengthy essay could tell. He never alluded to his hobby, double-star observing, except to men of similar taste. Even in the seventies he was better known to the astronomers in St. Petersburg, London, Berlin, Paris, and Rome than in his own country. Burnham was born in Thetford, Vermont, on December 12, 1838. Except the fact that he attended the Thetford Academy during his young years nothing is known about his early youth. He served in the Civil War and toward its end he was the shorthand reporter at the U. S. Army Headquarters at New Orleans. While there, he purchased at an auction Burritt's "Geography of the Heavens" and this so aroused his interest that he purchased a cheap, small telescope to satisfy his astronomical curiosity. In 1866 we find Burnham in Chicago as court reporter, buying the second astronomical book for his library, Webb's "Celestial Objects for Common Telescopes," and his scientific career well begun. The famous 18½-inch Dearborn refractor had been recently installed near his residence. This made him feel the need of a better telescope for his own work in his hobby. Reckless with regard to expense, like any true amateur, he ordered from Clarks the best lens for a 6-inch refractor that they could furnish him. The price for this lens, after delivery, was $800.00. He was in a short while in correspondence with most of the famous double-star astronomers in Europe and astonished them by the excellent results he got with this six-inch lens. His observatory was a backyard affair, homemade in every sense and called the "Cheese Box" by the neighbors. There was naturally a good deal of talk in the neighborhood about this mysterious man and his queer doings, but Burnham was too busy daytimes in the court rooms and nights at his telescope to pay any attention. The rumors of the neighborhood had it that the "Star Gazer" was busy with fortune telling, necromancy, and magical incantations in that Cheese Box. Some of the bolder younger couples approached him about their future, but Burnham rejected fame and fortune and turned all inquiries aside with his own sense of humor.

The 18½-inch Dearborn refractor was controlled by the Chicago Astronomical Society, an amateur society, and had for its director from 1866 to 1876 T. H. Safford. During that time Burnham made some of his famous observations with that instrument, perhaps as a guest observer. He was even elected honorary director after Safford left, but only for a few months. Something happened, we do not know what, and Burnham's directorship was rescinded on April 11, 1877. The

Observatory was closed to him merely by changing the locks. This action of the Society sounded a war cry in the leading daily papers. Burnham was always popular with the press. Papers in New York, Boston, Cincinnati, and his own Chicago took up the fight. Even the dignified *Journal of Science* at New Haven condemned the Society's action. The result was that all was amicably settled and double-star observations were continued with the Dearborn refractor. It should be said also that genial Professor G. W. Hough was then the director.

From 1879 he continued as advisor with the Lick Trust during the construction period and in 1888 he came to reside permanently on Mt. Hamilton as the ranking astronomer of the first staff. He always wished to remain an amateur astronomer and had a strong feeling that as soon as one gets paid for his hobby, the joy of his work is killed.

Burnham's personality was of the type most anyone would be pleased to meet. He was a man of the world due to the rich experience he had gained in the Circuit Court. He had a pleasant sense of humor, bordering on the mildly sarcastic side, which pleased everyone with whom he came in contact. He was also a man who hated all pretense and sham and despised all those who rushed into print before they had any real thing to explain. Visitors coming to the Observatory in the early days found themselves well repaid for the hour-long, tiresome journey up the mountain road if they found the opportunity either to speak or listen to Burnham. The daily press was always friendly toward him and praised him enthusiastically. His public lectures were always a success. He left many friends behind him in all stations of life when he retired from the Lick Observatory and California.

John M. Schaeberle

The next man on the staff was J. M. Schaeberle. When he died at Ann Arbor, Michigan, September 17, 1924, a short notice appeared in the *Publications of the Astronomical Society of the Pacific* saying that the last member of the original staff was gone, and nothing more. There is little in the Observatory records which can throw much light upon this man. As an astronomer, he was evidently of promise when Holden engaged him for the meridian circle of the Observatory. He was also evidently a born bachelor, that kind who during his whole life attends the Y.M.C.A. gymnasium regularly, taking care of himself and his health in a common sense way. His interest in music and civic affairs was his only recreation. His was a quiet sort of personality, never giving offense to anyone, but having a strong mind all his own. He was born in Germany on January 10, 1853, and came to the U.S.A. the next year. His parents were hardworking immigrants who settled in Ann Arbor, Michigan. The height of their ambition was to have their boy learn a trade which would support him in better circumstances than life had given them. So he was apprenticed in a Chicago machine shop for three years from 1868 to 1871. During that time he became interested in astronomy and attempted to make small reflecting telescopes, so he

was one of the first of the great future fraternity of amateur telescope makers in the U. S. He felt the need of higher education and decided to go back to his home town to finish high school and go to college. He must have been a very good student for he finished his high school and college training in five years, graduating from the University of Michigan in 1876. The mechanical skill acquired as machinist helped him to make successful mirrors from 8 to 24 inches in diameter. He discovered several comets about this time and so established his reputation as an astronomer. After graduation from college, he became an assistant and later instructor at the University Observatory at Ann Arbor. He was connected with the University of Michigan until 1888 when Holden had him appointed to his first staff. The first five years of his life at the Lick Observatory he had charge of the meridian circle. He was a good all around astronomer.

Holden placed him in charge of the first Lick Observatory eclipse expedition. He and Keeler observed the total eclipse of the sun in northern California. This was on January 1, 1889, the beginning of the many eclipse expeditions sent out by the Lick Observatory in the years to come. Schaeberle and Burnham together observed the total eclipse of the sun that took place the same year, December, 1889. For this they traveled to Cayenne, South America, and Schaeberle used a 40-foot camera lens of his own design. This was used on most future eclipse work by the Observatory. This lens was used to photograph the corona. It was used again when Schaeberle went to Chile for the eclipse of April, 1893. He went to Japan for the eclipse to be seen there in 1896 but this time clouds interfered.

When Holden retired, Schaeberle, as the senior astronomer, was made the acting director of the Observatory. He served in that capacity for several months. When Keeler was called back to the Lick Observatory as director, Schaeberle retired for good and took a trip around the world. He then settled in his beloved Ann Arbor where he lived by himself with his garden and flowers, a quiet settled life.

During his stay at the Lick Observatory, he was the senior member of what was then called the bachelor mess, consisting of the staff members who were single. To lend proper dignity to that institution, no assistants or students were admitted. His company was enjoyed by the few members for his view of life in general which was more poetic than practical. In short, he was a man who could live with himself and like it. Visits to the near, small city of San Jose were about the most exciting events in his life. He enjoyed these fully and kept the bachelor mess informed for days of his mild adventures that took place there.

James E. Keeler

Early in 1886 James E. Keeler, on the recommendation of President Holden of the University of California, was appointed Assistant to the Lick Trust with service on Mt. Hamilton. He arrived there in the

later part of April and resided on the mountain over two years before his appointment as astronomer of the Lick Observatory's first staff. Holden had him in mind for the spectroscopic work in connection with the large 36-inch telescope.

Keeler was born in La Salle, Illinois, on September 10, 1857. He entered the still very young Johns Hopkins University in 1877 majoring in Physics and German. He graduated from this institution in 1881. At the end of his freshman year he accompanied Professor Hastings, a member of the Total Solar Eclipse Expedition sent to Colorado by the Naval Observatory. Holden, as already stated, was in charge of the party stationed at Central City. This eclipse took place on July 29, 1878. After his graduation from the Johns Hopkins University, Keeler went as assistant to Professor Langley, Director of the Allegheny Observatory. One of the Johns Hopkins professors, a physicist, recommended young Keeler to Langley because "Keeler doesn't claim to know everything." He went with Langley on the now famous expedition to the summit of Mt. Whitney, California, where both worked for some three months on the determination of the Solar Constant.

Keeler spent a year in Germany from 1883 to 1884 studying physics in Heidelberg and Berlin, returned to the Allegheny Observatory, and remained there until his appointment as assistant to the Lick Trust called him to Mt. Hamilton. It is no exaggeration to say he was the best trained scientist of the first staff and is now considered as one of America's great astronomers. His success with the visual star spectroscope, once called the "Keeler spectroscope," was epoch-making in his days, and his published results are a classic in astronomical literature, still consulted by modern investigators. He stayed for three years at the Lick Observatory, then left to become the Director of the Allegheny Observatory, succeeding his former chief and friend, Langley.

After Holden's resignation from the Lick Observatory, the Regents appointed Keeler the director. His appointment was dated March 8, 1898. He died suddenly on August 12, 1900, in San Francisco at the age of 43. His death ended a most promising scientific career and was a great loss to astronomy in the United States. Apparently, he was beloved by all who knew him; there was never a word, or even a hint, by any of the old timers, astronomers or workmen, that his administration was not the most perfect. The California newspapers were always friendly to him in contrast to Holden. There are still the children, now grown up, of his many friends here in California who remember Professor Keeler, the genial astronomer who could tell them the funniest stories over fifty years ago.

Edward Emerson Barnard

Edward Emerson Barnard was 31 years old when he came to the Lick Observatory as a member of the original staff. He was born on December 16, 1857, in Nashville, Tennessee. His father died before Edward was born, leaving his mother in very straitened circum-

stances. Since he went to work at the age of nine in a photographic studio in his home city, his formal early schooling must have been meager. He worked for sixteen years in this studio, becoming an expert photographer and acquiring an ever increasing interest in optical matters related to photography. His first astronomical contacts were formed by reading Dick's "Practical Astronomer" and reading this book led him to the purchase of a five-inch telescope, like any true amateur astronomer. He had his telescope in 1877, the year he met the great Simon Newcomb to whom he related his ideas about photography as applied to astronomical observations. Newcomb encouraged the young man, giving him good practical advice. This advice was followed by diligent application and by 1881 he could announce his discovery of a comet. Within a year or so he discovered several comets, and made his reputation as a keen, reliable observer. He received from the Vanderbilt University at Nashville a Fellowship in astronomy, being placed in charge of the small observatory which had a six-inch refractor. He published his observations in various astronomical journals here in the United States and in England. Holden recommended him for appointment in the Lick Observatory and thus he became a member of the original staff on June 1, 1888.

Barnard stayed with the Lick Observatory until 1895 when he accepted a professorship at Yerkes Observatory of the University of Chicago. While at the Lick, he established an extraordinary record as a discoverer of comets and the fifth moon of Jupiter, and as celestial photographer. He was very popular among the people of the State of California and was much in demand for popular lectures before churches, Y.M.C.A. meetings, Chautauquas, and such organizations. Newspapers always printed his success in glowing terms and never quite forgave him for leaving California. He died in Chicago on February 6, 1923.

Charles B. Hill

There is still another member of the original staff of whom we know little now. This was Mr. Charles B. Hill of San Francisco. Mr. Hill's appointment read: "Assistant Astronomer-Secretary-Librarian," but he was also the meteorologist, bookkeeper, and go-between for Holden and the rest of the staff. Hill was evidently an amateur astronomer active at the time when the Lick Observatory began to function. Holden, at first, offered this position to H. E. Mathews, the Secretary of the Lick Trust, but, as Mr. Mathews tells us in his reminiscences, he declined. His reasons were that his salary as Secretary of the Trust was higher than the highest salary paid to an astronomer and his contacts with big businessmen in San Francisco were such that he was assured of future engagement of his services after the Lick Trust should be dissolved. And, thirdly, he emphasized the feeling he had toward Holden, whom he considered too cold and formal for a possible harmonious relationship. He had found Holden a difficult man to work with when dealing with

the Trust's affairs. So Holden selected Mr. Hill. Hill stayed at the Lick for only one year or so. He was a married man, and living on the mountain with a family was not then as comfortable as it became years later. He returned to San Francisco, still calling himself an amateur, and wrote now and then for the papers. He took part in the newspaper controversy between Holden and the San Francisco papers, sometimes on one side, sometimes the other, evidently having a good time watching the life on the mountain from San Francisco. What became of him later is not recorded in any of the files available at the Lick Observatory.

John McDonald

John McDonald was the foreman under Thomas Fraser during the construction period of the Lick Observatory after 1880. He was an all around mechanic but his trade was that of a skilled machinist. He leveled the top of Mt. Hamilton to make room for the main building, installed the water system and power plant at the spring, and built the reservoirs and houses for residences, shops, and barns. In 1885 he married and brought his young bride to the mountain where they resided until his death in 1910 on Mt. Hamilton. Their daughter, Mary, was the first child born to Lick Observatory people and was also the first youngster married there. She is now Mrs. Ralph E. Wilson of Pasadena. The McDonalds had another daughter, Eileen, who is married to a prominent physician in San Francisco.

The McDonalds were a delightful family, beloved by everyone. He served under four directors; Holden, Keeler, Schaeberle, and Campbell, and his passing was greatly lamented by the community.

Early Work of the Observatory

When Holden became the Director on June 1, 1888, the Observatory was far from being a complete establishment, ready to function. The Lick Trust was still responsible for some work which was underway and neither Captain Floyd nor Mr. Fraser was here to supervise. Captain Floyd's health had been failing for some time and he had left the mountain to seek a rest. It became Holden's additional duty to see that all this was done and it was far from an easy matter. The authority to supervise was in one sense split, since all the Trust's business had to go through the San Francisco office of Mr. Mathews, the Secretary of the Trust, and that slowed up matters. Moreover, the workmen sent up were rather a troublesome lot. There was drinking and fighting among them, which Holden had to settle.

During Holden's first five weeks in office, he wrote 504 letters, all in his own hand. Over one hundred were to Mathews alone concerning the buildings, instruments, and administration in general. Provisions had to be made for the coming winter months on the mountain and improvements of roads and telephone lines, firewood for heating the offices and observers' rooms, etc., had to be considered.

There are many letters to prominent astronomers about Holden's proposed working plans for the staff and about his hopes for the future of the Lick Observatory. There are many letters concerning the Observatory and staff to the Secretary of the Regents of the University, Rev. J. H. C. Bonte in Berkeley. This Dr. Bonte was for many years connected with the University and was a powerful figure who had to be handled tactfully. Holden succeeded where other heads of departments failed. There is one letter to Simon Newcomb, dated June 20, 1888, which is of historical interest. Newcomb was evidently sick at the time and Holden wished him speedy recovery and recommended to him a prominent physician in Washington, D. C. In the same letter Holden asked Newcomb to second the nomination of Burnham to be a member of the National Academy of Sciences. What Newcomb's reply was is not known as there is no record in Holden's file of letters, but evidently, it was encouraging since, on July 8, 1888, Holden wrote five letters, all of the same tenor, to Professors Peters of Clinton, N. Y., Hilgard of Berkeley, Davidson of San Francisco, Rogers of Waterville, Maine, and LeConte of Berkeley. Burnham was never elected to be a member of the National Academy and, in all probability, he was the person least concerned with such matters.

There is another letter written by Holden at that time which is of historical interest in connection with the Astronomical Department of the University of California. In it he advised a young graduate of the University of Michigan named Armin O. Leuschner to pursue his graduate studies in astronomy at the Lick. Leuschner was not quite sure whether to continue his studies here in the United States or go to Europe and seek there a higher degree. Holden now wrote several letters including two or three to the Regents about his first graduate student and succeeded in having young Leuschner come to the Lick Observatory as a fellow. There was then no money available for a fellowship, but the young man could afford to pay his own expenses. Thus A. O. Leuschner enters the picture at the Lick Observatory and the University of California as the first graduate student right from the beginning of the Observatory in 1888.

One wonders where a man like Holden with his orderly methods of doing anything found the time to accomplish so many things so well. All his correspondence was written in vermillion copying ink and copied by the old fashioned hand press. All his letters are to the point, none are too long except those open letters to the press. They are certainly never boresome, even though one finds his military manner in all of them.

From the start, he was busily engaged in composing printed forms for this or that purpose and all forms are carefully pasted in a volume for record. He kept several notebooks on his desk about every item concerning the Observatory. He made entries about the water supply from day to day, keeping track of the water to the hundredth part of

a gallon and similarly for the firewood to the hundredth part of a cord.

Newspaper reporters were after him day and night asking whether any sensational discoveries were being made and were never quite satisfied with his statements. They grew suspicious that he was withholding valuable news from them. The rumor soon spread that he was sending "discoveries" to some foreign news service—for pay. Articles from the Lick Observatory which appeared in the *Monthly Notices of the Royal Astronomical Society* or *The Observatory*, etc., aroused the California papers to a feeling of neglect. The fact that Holden then wrote ever so many articles for the newspapers, explaining the why and wherefore, helped him little.

He was eager to have good relations established with the many visitors who came to the Lick Observatory by horse-drawn vehicles. The Trustees had a Visitors Room set aside in the main building during the construction period for that purpose and Holden continued the practice. The visitors were requested to obey the rules and sign the Visitors Register. There are now eleven large volumes in the library full of the names of those who came to the Observatory from 1885 until 1915, when the practice of having visitors sign was discontinued. These signatures of thousands of men and women from every part of the world make interesting source material, historically considered.

The Register kept during the construction period ended April 21, 1888. The last two names in this book are "E. S. Holden of San Francisco and Ambrose Swasey of Cleveland, Ohio." A note at the end in Holden's handwriting states "This book is to be replaced by a new one which is to be catalogued in the library." A new book begins with the same date, April 21, 1888, and the first names are the signatures of John S. Hager, San Francisco, T. G. Phelps, Belmont, A. S. Hallidie, San Francisco. All three were members of the Regents of the University and were the special Lick Observatory committee. Then the names of Ambrose Swasey of Cleveland, Ohio, Edward S. Holden of San Francisco, and E. C. Holden appear. The latter was "Ned," Holden's only child who must have been a boy about 7 or 8 years old.

Holden kept track of the number of visitors throughout his residency on the mountain and at the end of each volume of these visitors books a summary is to be found. For the first year of the Observatory's existence, 5801 visitors are recorded, for the second year one finds 4665. For the total of the eleven volumes from 1888 to 1915 there are over 100,000 signatures. It was found expedient to discontinue this practice of having visitors sign. One reason was that the crop of youngsters of the Mt. Hamilton community was passing through the grade school years, learning to use pen and ink. On public nights, they found their way into the visitors room and were tempted to sign their names in the register among the "outsiders." Their progress in penmanship may be followed as one goes through the books. Moreover, these youngsters had various places of residence as their geography progressed.

Thus places like Timbuktu, Africa, Kobe, Japan, St. Petersburg, Russia, Peking, China, etc., are found after their names. And so this good thing came to an end.

Holden promised to himself, and also to the public, much of his contemplated photographic "Moon Atlas." He wrote so much about it that the astronomical world considered his statements too optimistic. "Holden discovered the Moon" was a phrase used by several astronomers at meetings in the East. It was for this purpose that Holden persuaded the Lick Trust to order the 33-inch correcting lens to be placed in front of the 36-inch objective in order to change the large telescope into a giant camera. One must realize that no one at that time had any experience with direct photography with such a powerful instrument and the importance of the absolutely perfect seeing conditions for such photography was not understood. Reasonably good photographs were obtained but not so good that history was made by them. The additional lens cost something like $14,000 and has never been used since Holden's day. Some of these photographs were enlarged by Professor L. Weineck of the Observatory of Prague, Bohemia, now Czechoslovakia, and were reproduced by the K. K. Militaer Institute of Vienna. These enlargements were pretty pictures to look at, but are of little scientific value.

The Lick Observatory's First Eclipse Expedition

Shortly after Holden became the director, he made plans for the coming total solar eclipse which would be visible in northern California on January 1, 1889. Numerous articles by Holden in the daily papers informed the public about this event. He announced his plans for the Lick Observatory's eclipse expedition, the first of many to follow. He placed Keeler in charge, Barnard to look after the photographic work, and Leuschner to take the photometric observations. He, himself, and Schaberle made observations of the partial eclipse on Mt. Hamilton and he informed the public that the Observatory would be closed for visitors during that day. The newspapers resented this order, especially the papers of the neighborhood city of San Jose and from that time these papers had no more good words to say for Holden.

(To be continued)

Some Contributions of the Interferometer to Double-Star Research*

By RAYMOND H. WILSON, JR.

I am going to speak to you on a topic which is rather an old standby among my interests, as those of you who have heard me speak as long

*Address of the retiring president of the Rittenhouse Astronomical Society, at its monthly meeting on Friday, January 13, 1950.

as ten years ago must well know. However, the general principle of interferometry, meaning technique employing the interference of waves to make observations, was a key to one of the most powerful instruments developed for the purpose of winning the recent war, namely, radar. With this instrument, the distance of an object is measured by interference of waves reflected from the object with the direct radio waves emerging from the instrument.

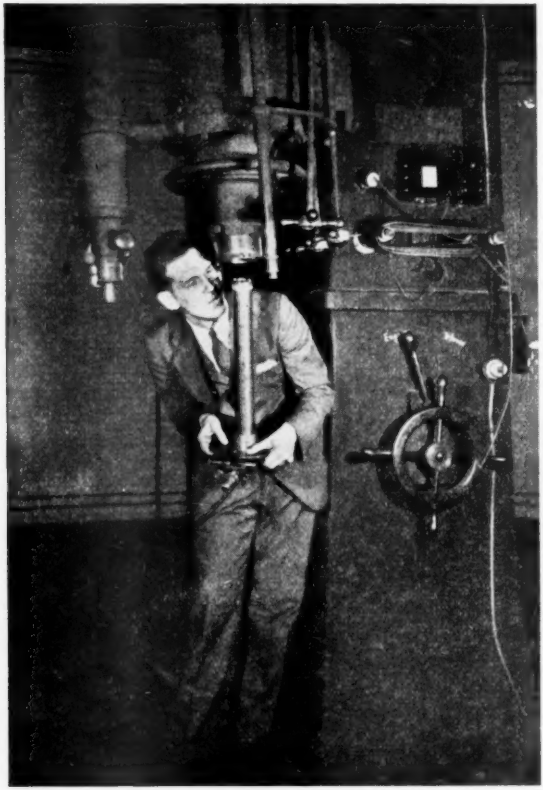
Since the war, this instrument has been turned to astronomical applications such as finding the distance to the moon. Then from general adaptation of this instrument has come the new science of Radio Astronomy, which Dr. Otto Struve of Yerkes Observatory has been describing in the *Sky and Telescope*. In fact, this month's number tells of an interference type of radio telescope which has resolving power far greater than any other (*i.e.*, about 6′ of arc). In a recent letter, Dr. Struve mentioned that interference methods have led to unexpected triumphs in analysis of the fine-structure of spectral lines. Hence it is all a growing technique, and my present review of its history and applications to visual astronomy seems to have timely interest.

As its name suggests, the instrument known as an interferometer is constructed to produce interference between two beams of light-waves from the same source which have transversed a slightly different path and later form a combined image. Then where the light of the two beams has had path-lengths differing by an odd number of half wave lengths, the crest of one wave will coincide with the trough of another,

PHOTOGRAPH 1
INTERFEROMETER TUBE WITH A SLIT-SCREEN IN PLACE.

and the net result will be darkness at that point. Nearby the path-lengths may differ by an integral number of whole wave lengths, so that the waves from the two beams will reinforce each other and the net result will be double the average light at that point. Thus the image will be crossed by a number of almost equally-spaced dark fringes aligned perpendicular to the line between the apertures admitting the two separate beams.

When such an instrument was first arranged by Thos. Young in England about 150 years ago, the wave theory of light was still an unproved speculation. Hence for the following half century, an interferometer was of interest chiefly as proof of the wave theory of light. The use of its principle for accurate *measurements* was first pointed out about 1880 by the American physicist Michelson, and much of his



PHOTOGRAPH 2
ATTACHING THE INTERFEROMETER TO THE 18-INCH REFRACTOR.

research activity until his death about 20 years ago was devoted to exploiting and forwarding this principle. As a volunteer naval research worker during the first World War he invented the range finder, which has been modified to the modern radar, mentioned above. But Michelson was most enthusiastic about the astronomical application of interference which began with his measurements of diameters of the satellites of Jupiter in 1890, and culminated with diameters of Betelgeuse and other giant stars in 1920.

The latter feat was accomplished by a special 20-ft. interferometer attached to the (then) new 100-inch telescope on Mt. Wilson. This interferometer gave measurable diameters for only some half dozen stars. A larger 50-ft. interferometer constructed later was intended to extend this diameter work by Pease, who died before much new could be accomplished.

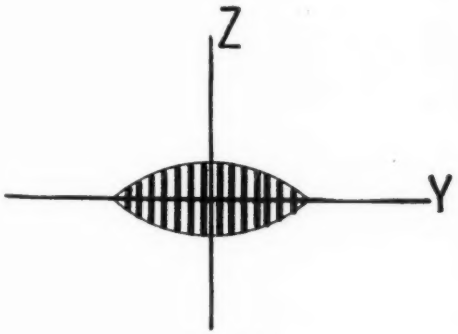


FIGURE 1
IMAGE OF A SINGLE STAR GIVEN BY THE INTERFEROMETER.

This last interferometer is very difficult to handle, as I can assure you from first-hand acquaintance, since I was invited to Mt. Wilson to try it out in the summer of 1938, just after the death of Dr. Pease. After a couple of months' practice I was just beginning to get a few doubtful results. Then along came discovery of a new satellite of Jupiter, the calculation of whose orbit offered some more certain achievement, so the interferometer was deserted. The large dimensions of this instrument made its operation so clumsy and adjustments so time-consuming that it was generally impractical. This is probably the reason that no results from it have been published since.

Another problem in astronomy where accuracy and high resolving power are needed is that of double stars. Keeping track of their relative positions is necessary for finding out about the true orbit and other interesting facts of a particular pair of stars. Doing this by photography could be discussed by Miss Lippincott or anyone else from Sproul Observatory. The great majority of such measurements have been made by directly viewing the double star through a large tele-

scope; and, concerning this, Dr. Barton and Dr. Olivier would have plenty to say.

But the interferometer is also of great potential use in this problem, as was originally pointed out by Michelson. Figure 1 shows the general appearance of a single star as viewed through the Flower Observatory refractor with an interferometer attached. The apparent separation of these fringes, in seconds of arc, can be accurately calculated from known dimensions of the telescope and interferometer. Then it is easy to understand how, if a star is double, the fringe distance can be used as a measuring stick to find the apparent distance between the two stars. The diagram in Figure 2 shows the plan. The slits of the interferometer,

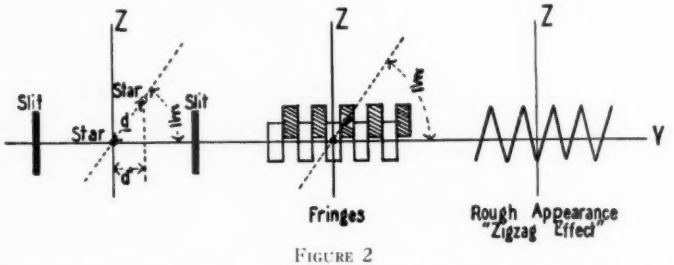


FIGURE 2

THEORY OF DOUBLE-STAR MEASUREMENT WITH THE INTERFEROMETER. RELATION OF STARS TO FRINGES AT A POSITION OF MINIMUM VISIBILITY.

which admit the interfering beams, are mounted so that their orientation can be adjusted by rotation and read off at any time. Then when the fringes are oriented so that the distance between them equals the projection on the distance between the double-star components, there will be a minimum visibility of the bright and dark fringes in the image as a whole. Several settings on these positions of minimum visibility will yield the usual measurement data for a double star. The arrangement of the slit mounting, also its size and method of application to the 18-inch refractor, may be generally understood from the photographs.

In all I have made several hundred measurements with the instrument at Flower Observatory, the most recent set being made during last summer's school vacation. In recent years the only other astronomer following this technique has been Dr. Hamilton Jeffers, who has used the 36-inch Lick Observatory refractor.

I will close by describing a couple of recently noted stars whose interesting characteristics were directly obtained by interferometric measures. One of these is number 11468 in Aitken's *Catalogue of Double Stars*. When I took its measure early last July, I noticed that the orientation of one of the stars with respect to the other had changed by 30° or so from that which I had found when I first measured it some 15 years ago. This led me to look up measures of the star by other astronomers, and I found quite an interesting list available. For one

thing the star's orientation had changed by 150° since its discovery by Aitken at Lick Observatory in 1906, so there appeared hope for drawing and calculating an orbit for the pair. It turned out that one star makes a complete circuit around the other in about 185 years. From this fact and the scale of the orbit, which is an ellipse about 0".4 long and 0".3 wide, it is possible to estimate a parallax of the star based on statistical knowledge of its spectral type. With the present data this parallax comes out 0".003, as compared with 0".006 found by Russell and Moore, who estimated it from only the mean angular motion, since no orbit was available to them. The reason they were deceived is that the periastron point of the orbit, where the motion would be the fastest, just happened to fall in the middle of the interval they worked with.

This new estimate of the parallax puts the stars twice as far away and makes them 4 times as powerful in intrinsic luminosity, which comes out to be nearly 400 times that of the sun for each. The most extraordinary deduction is that the combined mass of the two stars is 17 times that of the sun, which is much greater than that found for any other visual binary whose orbit is known and is quite rare in stars of any description. Another point of distinction would seem to be that this orbit has been based on an unusual number of interferometer observations: three different years by myself and four by Jeffers.

Another notable find this last summer was that o^1 (or 31) Cygni, a third magnitude star just west of Deneb, appears as a double star with the interferometer. The separation was only 0".06 which is too close to be observed directly with even the largest telescopes.

The reason such a measurement could be made with the interferometer attached is that the process of forming interference fringes is more than twice as delicate as that of forming an ordinary image with the telescope lens. Hence stars which are only 0".15 apart just fit the fringe-width measuring stick, while two stars must be almost twice the distance apart to be clearly visible directly with the 18-inch refractor. Also, with the interferometer stars may be noted as double down to ⅓ of this 0".15, fringe-width separation, since there would be a proportional narrowing of the fringes when the slits were oriented with the stars.

But the most striking part of the story of 31 Cygni turned up only about 3 weeks ago, when I found that the star had been discussed as a spectroscopic binary by 3 or 4 investigators. The latest of these, Miss Julie Vinter Hansen, had published a paper in 1944 in which she had practically predicted my own measures last summer, although before these no one had seen the double visually. The stars revolve in about 10 years and also turn out to have a large combined mass—about 18 times that of the sun.

It is in looking at just such stars as 31 Cygni, which are too close for direct view with any telescope, that I believe lie some of the best future possibilities of observation with an interferometer. I found a half dozen other new stars last summer, but none happens to have the fortu-

nate confirmation of 31 Cygni. Doubtless many even more interesting specimens remain to be discovered.

In conclusion, I wish to thank all members of the Rittenhouse Society for their coöperation during the past year in our effort to make the meetings interesting. As with my interferometer investigations, being your president for a year has been most satisfying work, and I shall be glad to stand ready to contribute anything I may in the future.

Bradley Observatory of Agnes Scott College

By WILLIAM A. CALDER

The dedication of Bradley Observatory of Agnes Scott College, Decatur, Georgia, took place on June 3, 1950. This was a particularly joyous occasion inasmuch as this beautiful building is the first adequate observatory in an important area of the Southeast. Hundreds of students and visitors will have their lives enriched because of the vision and prodigious effort of Dr. James R. McCain, president of the college.

The largest contribution to the project was a gift of $50,000 made by the W. C. and Sarah H. Bradley Foundation of Columbus, Georgia. The Aluminum Company of America donated the quarter-inch aluminum plate and structurals for the dome which was fabricated, largely as a gift, by the R. D. Cole Mfg. Co. of Newnan, Georgia.

Bradley Observatory of Agnes Scott College

The 30-inch reflecting telescope was formerly owned by Mr. Henry C. Gibson of Jenkintown, Pa. Its mounting was made by the Warner and Swasey Co., and the optical elements were made by the J. W. Fecker Co. This fine instrument was completely refurbished and modi-

fied by the Perkin-Elmer Corporation to suit Dixie latitude. It is now known as the Lewis H. Beck Telescope inasmuch as $10,000 toward its purchase was contributed by the Beck Foundation of Atlanta.

At the foot of the pier, in the main lobby, is a plaque giving the geographical co-ordinates of the pier as determined by the U. S. Coast and Geodetic Survey. The surrounding walls have spaces for photographs and transparencies which are being given by members of the Atlanta Astronomers who will be using Bradley Observatory as headquarters. At the left of the rotunda is a lecture room with seating capacity of 125. This has a small stage which, by strange coincidence, is ideal for chamber music. The first floor has a large room for telescope-making activities, darkroom, library, and offices. One of the most attractive features is the fourteen-foot planetarium dome which is far superior to the parachute under which the school children of the region were formerly stacked. A gift of a thousand dollars toward this room was made by Mr. Mandle Zaban of Atlanta.

There is a large flat roof for constellation study, and for the use of portable instruments which can be stored in a room beneath the telescope. Ample space for laboratory work is provided in the basement.

The Research Corporation of New York has contributed $3,100 for a photoelectric photometer (being constructed by the John F. Jewett Co. of Amherst, Mass.) and a two-prism slit spectrograph which is being made by the Perkin-Elmer Corporation. There has been quite a skyslide at Agnes Scott College, with the number of students in astronomy trebling for three successive years until the enrollment comprised a fifth of the total student body. Astronomy courses at Agnes Scott College are being made available for credit to students of Emory University and Georgia Institute of Technology, an arrangement which might be expected to have many advantages.

AGNES SCOTT COLLEGE, DECATUR, GEORGIA.

The Planets in September and October, 1950

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. During this period the sun will migrate 22 degrees southward toward more wintry declinations, so that by the end of October it will be more than 14 degrees south of the equator. The autumnal equinox will occur on September 23 at 9 A.M.

An eclipse of the sun will occur on September 11 beginning at 7:23 P.M., so that it will be invisible from all territories of the United States, excepting Hawaii and Alaska. In the latter territory it will actually appear total from the Near Islands of the Aleutians.

Moon. The phases of the moon will occur as follows:

Last Quarter	September	4	8 A.M.
New Moon		11	9 P.M.
First Quarter		18	3 P.M.
Full Moon		25	10 P.M.
Last Quarter	October	4	2 A.M.
New Moon		11	8 A.M.
First Quarter		17	10 P.M.
Full Moon		25	3 P.M.

The moon will be at perigee on September 15 and October 12.

A total eclipse of the moon will be timed for convenient observation on September 25. The partial phase will begin at 8:30 P.M.; totality will last for 23 minutes, beginning at 9:53 P.M.

An interesting occultation of the Pleiades will take place on October 27, beginning about 8 P.M.

Evening and Morning Stars. Mars will be low in the southwest, and Jupiter in the southeast, just after dark. The eastern dawn will display Venus during September, and Saturn during most of October.

Mercury. Since the fast planet will stand 18 degrees west of the sun on October 3, it should be easy to spot in the morning twilight for a week or more before and after that date. On September 24 it will pass 3 degrees south of Venus, and on October 10, 2 degrees north of the moon.

Venus. After having had a long, favorable display in the morning sky, Venus will become difficult to observe after October 1, when it will be rising after 5:30 A.M.

Mars. Although the sun is slowly catching up with it, Mars may still be seen low in the southwestern twilight. When it passes 3 degrees north of Antares, early in October, it will exactly equal that star in brightness.

Jupiter. Jupiter will be most convenient for later evening observation during this period. It will be reaching the meridian by 9:30 P.M. on October 1.

Saturn. Its conjunction with the sun on September 15 will preclude practical observation of Saturn during that month, but by the end of October it will be rising at 4 A.M.

Uranus. The motion of Uranus will change from slowly eastward to stationary, within 2 degrees to the south of ϵ Geminorum.

Neptune. Neptune will be practically unobservable during this period, owing to its conjunction with the sun on October 10.

Department of Mathematics, Temple University, Philadelphia, Pa.
July 10, 1950.

Asteroid Notes

By HUGH S. RICE

The following four asteroids are available for small telescopes at this time: 17 THETIS, magnitude 9.6, opposition August 21; 306 UNITAS, magnitude 9.7, opposition August 23; 39 LAETITIA, magnitude 8.8, opposition September 1; 511 DAVIDA, magnitude 9.3, opposition October 5.

ASTEROID EPHEMERIDES

For 0h U.T. Equinox 1950

17 THETIS			306 UNITAS		
	α	δ		α	δ
1950	h m	° ′	1950	h m	° ′
Aug. 17	22 2.1	−15 46	Aug. 17	22 12.9	−12 23
27	21 53.4	−17 0	27	22 5.2	−14 3
Sept. 6	21 45.8	−18 1	Sept. 6	21 57.9	−15 34
16	21 40.4	−18 42	16	21 52.7	−16 47
26	21 38.3	−18 57	26	21 51.2	−17 33

39 LAETITIA			511 DAVIDA		
	α	δ		α	δ
1950	h m	° ′	1950	h m	° ′
Aug. 17	22 51.3	− 6 22	Sept. 6	1 2.4	−16 46
27	22 44.8	− 7 53	16	0 57.3	−18 8
Sept. 6	22 37.6	− 9 27	26	0 50.7	−19 19
16	22 30.8	−10 57	Oct. 6	0 43.3	−20 14
26	22 25.7	−12 16	16	0 35.9	−20 47
			26	0 29.4	−20 54

Hayden Planetarium, American Museum of Natural History, New York, July 23, 1950.

Occultation Predictions for September and October, 1950

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1950	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Sept. 3	66 Arie	6.1	2 49.4	+0.7	+2.0	24	3 30.6	−0.2	+1.0	289
4	χ Taur	5.5	4 27.8	..	..	151	4 35.8	..	..	168
5	354 B.Taur	6.3	6 43.4	−0.4	+1.9	71	7 53.8	−0.9	+1.6	258
7	47 Gemi	5.6	6 48.7	−1.0	−0.6	147	7 20.7	+0.9	+3.4	212
7	BD+27°1337	6.4	7 18.5	+0.4	+2.4	52	8 9.3	−1.0	+0.2	306
17	135 B.Scor	6.0	23 35.8	−1.7	−1.2	121	0 42.8	−1.1	−0.8	249
21	ω Sgtr	4.8	0 18.5	−1.4	+1.3	28	1 19.8	−2.4	−0.8	293
21	*A* Sgtr	5.0	1 54.2	−1.4	0.0	65	3 9.8	−1.2	−0.5	247
23	152 B.Capr	6.5	3 24.7	−0.6	+1.3	19	4 27.4	−1.9	−0.9	268
28	π Pisc	5.6	1 36.6	+0.1	+2.5	17	2 29.8	−1.2	+1.3	274
Oct. 2	38 B.Auri	6.5	8 8.8	−2.3	−0.1	102	9 33.7	−2.0	+1.6	235
2	47 B.Auri	6.1	11 42.3	−1.9	+0.6	55	12 47.5	−0.6	−2.9	306
3	406 B.Taur	5.6	3 57.0	−1.0	−0.1	137	4 28.7	+1.0	+3.3	200
5	*c* Gemi	5.4	5 36.4	−0.1	+1.2	96	6 39.0	−0.4	+1.3	271
19	128 B.Capr	6.5	22 11.6	−1.4	+1.8	37	23 25.4	−2.0	+0.6	267
27	47 Arie	5.8	2 58.2	−0.4	+2.8	27	4 7.3	−2.0	+0.8	267

Date 1950	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
28	23 Taur	4.2	1 54.1	—0.5	+1.8	73	3 2.7	—0.6	+2.1	233
28	η Taur	3.0	2 35.9	—0.8	+2.0	68	3 50.1	—1.0	+1.9	238
28	27 Taur	3.8	3 52.3	..	..	140	4 10.7	..	..	166
28	28 Taur	5.2	3 39.5	—2.2	+0.5	106	4 38.3	—0.4	+3.4	200
31	49 Auri	5.0	7 18.9	—2.1	—0.1	106	8 48.6	—2.2	+0.4	260
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Sept. 3	16 Taur	5.4	12 18.9	—2.1	—0.3	82	13 47.0	—1.7	—0.1	245
5	354 B.Taur	6.3	6 39.3	+0.4	+2.0	50	7 35.4	—0.6	+1.0	280
7	BD+27°1337	6.4	7 27.7	+1.6	+3.5	25	7 51.9	—1.2	—1.3	334
17	135 B.Scor	6.0	23 4.4	—1.8	—0.7	128	0 16.8	—2.0	—0.3	255
20	ω Sgtr	4.8	23 43.4	—1.8	+2.3	26	0 35.3	—2.0	—0.3	308
21	A Sgtr	5.0	1 22.5	—1.7	+1.0	48	2 40.4	—2.2	—0.3	272
28	π Psc	5.6	1 37.2	+0.6	+2.9	357	2 6.0	—0.9	+0.5	301
Oct. 2	38 B.Auri	6.5	7 32.2	—1.4	+1.4	84	8 54.4	—1.5	+1.8	241
2	47 B.Auri	6.1	11 1.4	—2.2	+0.6	72	12 30.8	—1.9	—1.4	279
3	406 B.Taur	5.6	3 51.0	+0.2	+0.7	112	4 36.7	+0.6	+1.9	227
5	c Gemi	5.4	5 38.1	+0.5	+1.3	79	6 32.0	—0.1	+0.8	287
19	56 B.Capr	6.3	0 8.0	..	..	124	0 48.6	..	..	183
19	128 B.Capr	6.5	21 43.1	—1.1	+2.2	37	22 47.8	—1.4	+0.9	279
21	50 Aqar	5.9	0 45.8	..	..	123	1 11.7	..	..	163
27	47 Arie	5.8	2 58.2	..	..	347	3 20.8	..	..	311
28	23 Taur	4.2	1 47.4	+0.2	+1.9	53	2 47.8	—0.4	+1.5	257
28	η Taur	3.0	2 26.0	+0.1	+2.1	45	3 28.0	—0.8	+1.4	263
28	27 Taur	3.8	3 11.7	—1.0	+1.3	97	4 9.6	—0.1	+2.7	209
28	28 Taur	5.2	3 14.6	—0.8	+1.6	82	4 22.3	—0.6	+2.3	223
31	49 Auri	5.0	6 45.0	—1.5	+1.0	99	8 7.2	—1.7	+1.4	255
31	54 Auri	5.8	9 54.9	..	..	32	10 32.0	..	..	344
31	25 Gemi	6.5	11 8.8	..	..	33	11 38.8	..	..	353
Occultations Visible in Longitude +98° 0′, Latitude +31° 0′										
Sept. 3	16 Taur	5.4	12 8.0	—3.2	—2.0	113	13 22.2	—2.1	+3.1	208
3	q Taur	4.4	12 25.5	—2.6	+0.2	79	14 1.1	—2.2	+0.3	246
3	20 Taur	4.0	12 58.3	—2.6	—2.4	116	14 10.2	—2.2	+2.4	213
3	21 Taur	5.8	13 0.3	—2.4	+0.3	72	14 32.5	—1.9	—0.5	257
3	22 Taur	6.5	13 5.1	—2.3	—0.2	81	14 36.7	—1.9	—0.1	250
5	354 B.Taur	6.3	6 27.3	+0.6	+1.6	59	7 22.8	—0.2	+1.0	270
16	17 G.Libr.	6.4	1 35.1	—1.4	—2.8	159	2 16.7	—0.3	0.0	237
20	ω Sgtr	4.8	23 10.6	—1.8	+2.0	51	0 21.3	—1.8	+0.2	290
21	A Sgtr	5.0	0 57.6	—2.2	+1.4	59	2 24.7	—2.5	+0.2	265
23	152 B.Capr	6.5	2 51.3	..	..	340	3 14.2	..	..	315
Oct. 2	38 B.Auri	6.5	7 12.3	—1.5	+0.9	96	8 23.8	—0.9	+2.6	224
2	47 B.Auri	6.1	10 42.2	—2.9	—0.7	103	12 18.2	—2.7	+1.0	242
19	56 B.Capr	6.3	0 0.8	..	..	145	0 13.6	..	..	165
27	47 Arie	5.8	2 32.1	+1.2	+3.6	358	3 5.3	—2.1	—0.2	300
28	23 Taur	4.2	1 35.0	+0.4	+1.5	61	2 32.3	0.0	+1.4	250
28	η Taur	3.0	2 10.7	+0.3	+1.8	52	3 10.4	—0.4	+1.3	256
28	27 Taur	3.8	2 56.9	—0.9	+0.8	104	3 45.3	+0.4	+2.8	201
28	28 Taur	5.2	2 56.6	—0.4	+1.3	84	3 57.5	—0.1	+2.2	221
31	49 Auri	5.0	6 30.5	—1.7	—0.1	118	7 37.1	—1.0	+2.7	230
31	54 Auri	5.8	9 12.9	—2.6	+1.3	77	10 47.4	—2.6	—1.5	294
31	25 Gemi	6.5	10 30.4	—2.8	+1.3	85	12 3.8	—2.0	—2.1	299
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Sept. 2	47 Arie	5.8	13 36.1	..	..	135	14 9.9	..	..	176
3	16 Taur	5.4	11 14.1	—1.6	+2.1	58	12 44.4	—2.1	+1.2	247
3	17 Taur	3.8	11 9.8	—2.6	+0.5	97	12 23.7	—1.2	+3.2	207

Date 1950	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION *a*	IMMERSION *b*	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION *a*	EMERSION *b*	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′									
3	*q* Taur	4.4	11 49.8	−1.1	+3.2	30	13 7.3	−2.8	−0.5	276
3	20 Taur	4.0	11 56.9	−2.1	+1.5	68	13 31.0	−2.2	+1.2	241
3	21 Taur	5.8	12 23.5	−1.3	+3.3	29	13 39.5	−2.9	−1.1	280
3	22 Taur	6.5	12 22.6	−1.6	+2.7	39	13 47.3	−2.7	−0.5	271
4	BD+26°731	6.5	12 19.7	−2.5	+0.5	93	13 48.1	−2.0	+2.0	230
17	*b* Scor	4.8	3 9.0	−1.3	−0.9	87	4 17.8	−1.1	−1.7	293
21	*A* Sgtr	5.0	0 25.0	−1.5	+1.9	58	1 36.9	−1.6	+0.6	283
26	98 B.Pisc	6.4	7 9.9	..	..	117	7 37.5	..	..	155
27	ε Pisc	4.4	7 43.7	−3.0	+0.5	91	8 46.0	−0.2	+3.3	184
29	27 Arie	6.4	5 24.6	−1.4	+0.7	113	6 0.0	+0.8	+3.4	180
Oct. 2	38 B.Auri	6.5	7 10.2	+0.3	+2.2	47	8 10.6	−0.9	+1.0	276
2	47 B.Auri	6.1	9 59.8	−1.3	+2.4	57	11 25.3	+2.3	+0.4	270
5	ω Canc	5.9	14 27.2	..	..	35	14 46.8	..	..	8
20	50 Aqar	5.9	23 52.6	−0.8	+1.0	107	0 42.8	−1.0	+2.6	199
28	η Taur	3.0	2 35.1	+1.0	+2.4	13	3 6.8	−0.4	+0.3	302
28	27 Taur	3.8	3 0.7	+0.4	+1.5	65	3 57.9	0.0	+1.5	247
28	28 Taur	5.2	3 6.3	+0.5	+1.8	48	4 1.2	−0.2	+1.2	265
31	49 Auri	5.0	6 21.5	+0.1	+1.7	70	7 25.2	−0.8	+0.9	277
31	54 Auri	5.8	8 55.2	..	..	29	9 39.9	..	..	324
31	25 Gemi	6.5	9 47.7	−1.6	+2.8	58	11 4.1	−2.5	−1.5	304

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

The Chemical Composition and Some Physical Characteristics of Tektites

CHARLES R. HAMMOND

Hartford-Empire Company, Hartford 2, Connecticut

ABSTRACT

Accurate density-measurements are given for 2 australites and for 3 moldavites, and a chemical analysis, made of a moldavite, is compared with that of other tektites and with those of ancient and modern glasses. The chemical analysis is then used to approximate the coefficient of thermal expansion and other physical characteristics of tektitic material.

1. *Introduction.*—A few years ago, I obtained several small tektites (moldavites), each weighing about 2 gm., from Mr. F. W. Cassirer of Prague, Czechoslovakia. These specimens are characterized by their light-green, transparent, glassy appearance, and by their streaked and pitted surfaces. I have recently obtained for my collection also 2 other tektites (australites), which originally came from the Nullarbor Plain of Western Australia. These tektites are blackish-green in color. One is lens-shaped and transparent at the outer edge; the other is spherical and opaque.

An examination of the literature reveals that few data exist relative to the physical properties of tektitic glasses and that comparatively few chemical analyses have been made of tektitic material. In part, this condition may be ascribed to the fact that the chemistry and the physics of glasses are complex, and that special equipment is required for the study of glasses. Being associated at present with a company that develops machinery for the glass industry, I was fortunate in being able to have an analysis made of a tektite by experienced glass chemists, and in having special equipment made available to me.

2. *Procedure and Results.*—Accurate density-measurements, effected by aid of a Preston Density Comparator, were made on 3 moldavites and on 2 australites. The specimens were found to have the following densities:

TABLE 1

	Density at 20° C.
Moldavite Sample No. 1	2.3348
Moldavite Sample No. 2	2.3985
Moldavite Sample No. 3	2.3733
Average	2.3689
Australite—Spherical Sample	2.4549
Australite—Lens-shaped Sample	2.4477
Average	2.4513

These values agree closely with those tabulated by Barnes.[1]

The density of strained glass has been found to increase when the strain is removed by annealing. In some commercial glasses, differences in density of 0.005 have been noted between strained glass and the same glass when annealed. Altho the differences in density between the 3 moldavites or between the 2 australites are not due to strain alone, but to compositional differences as well, it was considered worth while to examine the samples for strain and homogeneity.

The tektites were immersed in benzene chloride and observed with a polarizing microscope equipped with a tint plate having a standard retardation of 565mμ. Moldavite Sample No. 1 was found to be highly strained. Substitution of a calibrated quartz wedge showed that one stria or cord in the tektitic glass was in compression. Measurements gave a retardation of 100mμ, indicating that the cord was under a stress of 1220 pounds per square inch. Another cord, in tension, gave a retardation of 60mμ, which is equivalent to a stress of 735 pounds per square inch.

On a scale of *A* to *E*, in which *A* indicates perfectly annealed or unstrained glass and *E*, dangerously strained glass, Moldavite Sample No. 1 was given a rating of *D*. Glass of grade *E* has regions with stresses exceeding 2000 pounds per square inch. A scratch on the surface of glass of this grade may lead to its disintegration, much in the same manner as is observed in Prince Rupert drops when the tail is severed.

Examination of Moldavite Sample No. 2 showed at least 2 cords with stresses about equal to those found in the first sample. Moldavite Sample No. 3 was, however, only slightly strained and had no region that showed stresses greater than 25 pounds per square inch. Large bubbles and smaller bubbles, known as seeds, were present thruout its structure. These were not noticeable in the first 2 samples.

The outer edge of the lens-shaped australite also was examined for strain;

this was found to be almost free of stress. The other australite was opaque and could not be examined without damage to the specimen.

Polariscopic examination of the tektites showed that the first 2 moldavites were composed of heterogeneous glass that had cords of chemical composition varying from that of the rest of the mass. It may be concluded that initially the glass was formed rapidly and that it did not have an opportunity to become homogeneous thruout. The presence of bubbles in the case of Moldavite Sample No. 3 also supports this belief, as gases evolved in the glass-making process did not have time to escape from the viscous mass; furthermore, the presence of bubbles and the cordiness of the glass may indicate also that the glass was formed at a temperature not far above that of its softening point.

One of the moldavites whose surface was free of contaminating material was chosen for analysis. The silica, soda, lime, and alumina contents were then determined by standard methods developed for analyzing commercial glasses. The iron content was found by a potentiometric means, and the manganese was estimated by a colorimetric method. The composition expressed in terms of the oxides was as follows:

TABLE 2

Oxide	*Percentage Composition*
SiO_2	78.46%
CaO	2.62%
Al_2O_3	10.83%
MgO	2.20%
Total Fe as Fe_2O_3	1.51%
TiO_2	0.32%
ZrO_2	None detected
P_2O_5	None detected
Cr_2O_3	None detected
MnO	0.06%
Na_2O	0.48%
K_2O	3.34%
As_2O_3	None detected
Sb_2O_3	None detected
CoO	None detected
NiO	None detected
S	None detected
B_2O_3	Not determined
F_2	Not determined
Total	99.82%

A comparison of this analysis with other analyses of moldavites shows good agreement. The magnesia content was, however, slightly higher than that in the analyses tabulated by Barnes.

3. *Discussion.*—It is interesting to compare the composition of this tektite with the composition of glasses of antiquity and of present-day commercial glasses.

Glasses of antiquity are characterized by silica contents ranging from 60% to 70%. To "work" these glasses with the fuels and implements then available, the ancients used a high-soda (Na_2O) content, which varied between 10% and 23%. Altho potash (K_2O) could have been used to replace the soda in these glasses, seldom has it been found to exceed 3%. Magnesia varied usually from 1% to 6%, whereas lime varied from 3% to 10%. The alumina content was ordinarily low, seldom exceeding 5%. Iron oxide was present usually as a contaminating material in quantities up to 2% or 3%.

With the exception of special optical glasses or glasses intended for unusual applications, commercial glass has, for the most part, followed the same general compositional pattern that has been used for thousands of years. It has been possible, however, to reduce the soda content and to increase the silica, and thus to obtain a more chemically durable glass that has greater resistance to weathering and to thermal shock. A recent survey made of 64 commercial container glasses gave the following average composition:[2]

TABLE 3

Oxide	*Percentage Composition*
SiO_2	72.5%
R_2O_3 (Al_2O_3, Fe_2O_3)	1.8%
CaO, MgO, BaO	10.4%
Na_2O, K_2O, B_2O_3, SO_3, F_2	15.3%

The average density of commercial container glass is about 2.500, and the seed count averages about 25 seeds per ounce of glass. These values are for glasses manufactured in the United States, and would not necessarily apply to glasses made in other countries. Window glass and plate glass follow the same general lines of composition.

A comparison of the composition of commercial glasses with that of the moldavite shows that the tektite has a much higher silica content than is normally encountered. High-silica content in glass indicates usually that the glass is more difficult "to work," *i.e.*, that it is more viscous at high temperatures, and that the glass has a lower thermal expansion than ordinary glasses. The softening temperature, the strain point, and the annealing point are also elevated in the case of glasses of high-silica content. In commercial glasses, soda is a principal component, but it will be noted that, in the tektite analyzed, it is a very minor component and is exceeded by the potash content. Low-alkali content in glass is usually an indication that the glass has low thermal-expansion properties.

The characteristic greenish color of these moldavites can be attributed to both the iron and the manganese in the glass. Normally, iron alone colors glass green and manganese alone gives glass a purple color. In fine glasses, the presence of as little as 0.1% iron is considered detrimental. In commercial glasses, however, where iron-bearing sands are used, it frequently becomes necessary to use a decolorizer. Manganese dioxide is the classical decolorizing agent used for this purpose. This agent serves both to oxidize the iron to a state of lower valence and to color the glass itself, so that light is absorbed that is very nearly complementary to that of the iron in the tri-valent condition in the glass. The resulting effect is, therefore, to reduce the coloring effect of the iron. Were it not for the presence of manganese in tektites, the color due to iron would be probably more intense.

An effort to determine the softening temperature, the annealing point, and the strain point (equivalent to a viscosity of $10^{7.6}$, $10^{13.4}$, and $10^{14.6}$ poises, respectively) was made without success. Failure was due to difficulties in drawing a fiber of the tektitic material to the proper uniform thickness. These experiments suggest, however, that the sample had a high softening-point nearly equal to that of some commercial boro-silicate glasses, such as Pyrex. If tektitic glass were available in sufficient quantity, and if care were exercised, in all probability it would be possible to draw a suitable fiber for determination of the softening temperature, annealing point, and strain point, as well as the coefficient of linear thermal-expansion.

The Additive Theory, first proposed by Winklemann and Schott and later developed by Gehlhoff and Thomas,[3] postulates that a glass may be regarded, for purposes of computation, as a simple solution of its component oxides, and that each of these oxides may be represented by a number called a "factor." The effect is held to be proportional to the percentage by weight of the particular oxide that is present. If the percentage of each oxide be multiplied by its factor, the sum of the products should be an expression of the physical properties of the entire glass. Altho the Additive Theory cannot be said to be valid for all ranges of glass compositions, it has been found to be a useful tool when the physical properties of a glass are difficult to determine. It can be used with reasonable accuracy, provided the glass comes within the range of the original glasses from which the factors were derived. Factors have been derived for density, coefficient of linear and cubical thermal-expansion, scratch resistance, tensile strength, modulus of elasticity, bending strength, and index of refraction.

By using English and Turner[4] factors and by approximating factors, based on experience, for the minor components, a coefficient of linear thermal-expansion of 29.9×10^{-7} cm. per cm. per degree C. was obtained for the moldavite analyzed. This value compares with an average expansion value of 89×10^{-7} for commercial container glass and a value of 33×10^{-7} for Pyrex glass. If the value of the linear expansion thus determined is assumed to be approximately correct, moldavite glass should have a much greater resistance to thermal shock than has ordinary glass; furthermore, it should be possible to anneal such glass very rapidly without introduction of appreciable strain. If a rough value of 700°C. be assumed for the annealing point, and a value of 600°C. be assigned for the strain point, it should be possible to determine an annealing schedule for tektitic glass that would produce very little residual strain. For a specimen approximately ½ cm. thick, such as Moldavite Sample No. 1, it should be possible to anneal the glass to a very low degree of strain by heating the glass to a temperature of about 740°C., holding it at that temperature for about 1½ minutes, and then cooling the glass at the rate of about 10° C. per minute. After the glass has been cooled to 600°C., the temperature could be dropped much more rapidly without introduction of strain. Altho other annealing schedules will produce the same degree of annealing, the schedule given here should produce almost complete annealing in a minimum time. Such a schedule would probably not, however, relieve all the strain in cords in which differences in glass composition exist. The schedule does indicate, however, that Moldavite Samples Nos. 1 & 2, at some time in their history, were cooled, in all probability, very rapidly. The amount of strain present in these moldavites and the rate at which the glass can be annealed without introduction of strain suggest that the glass may have been cooled at a rate of 50°C. per minute or more, especially in the temperature region lying between the annealing and strain points.

As a check against density, a calculation was made by using English and Turner factors for the moldavite that was analyzed. A density of 2.33 was obtained; this checks closely with observed values.

This study indicates that it would be desirable to examine other tektites for strain and homogeneity, and, if possible, to make determinations of the softening temperature, the annealing point, and the strain point. An accurate measurement of the coefficient of expansion of tektitic glasses also would be desirable. It should prove interesting likewise to simulate a tektitic composition by fusion of sand, feldspars, and minor ingredients, and to explore this region of glass formation.

4. *Acknowledgments.*—I wish to express my appreciation to Messrs. Paul Webster, Robert Stewart, George Rucker, Leo Stadler, and Robert Poole, of the Hartford-Empire Company, Hartford, Connecticut, for their assistance, and to the Hartford-Empire Company itself for making available certain pieces of equipment and facilities.

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Trigonometric Criteria for Determining Whether Meteoritic Falls Lie on the Same Great Circle*

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ABSTRACT

This paper is divided into 6 sections, of which an enumeration will constitute its abstract: (1) introduction; (2) trigonometric criteria for determining whether a given point Q lies on the great circle passing thru 2 other given points, A and B, of north pole P; (3) and (4) methods of determining the geographic coördinates of pole P; (5) determination of the distance of a given point R from the great circle; and (6) determination of the coördinates of point S, the point on the great circle closest to the given point R. Several subtopics are discussed in the notes to the paper.

1. *Introduction.*—A means of testing whether the loci of meteoritic falls or of tektitic showers lie on the same great circle is desirable in a number of meteoritical problems, *e.g.*, that of the great-circle distribution of the tektites, which has been investigated by Lincoln LaPaz.[1] Because the requisite formulas are not contained in any treatise with which I am familiar, and because they may be of service to meteoriticists, they will be derived here. Evidently these formulas, or their equivalents, find application, not only in meteoritics but also in astronomy, navigation, and geography.

2. *Criteria that a Given Point Q Lies on the Great Circle of which P is the North Pole.*—Any 2, non-antipodal points on the surface of a sphere uniquely define a great circle. Let A and B be 2 such points on the surface of the Earth, assumed to be a sphere, point A being the more easterly one and arc AB being $< 180°$, and let P be the *north* pole of the great circle passing thru them, and C be the *north geographic* pole.[2] Denote the geographic coördinates, longitude and

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latitude, of points A and B and pole P by (λ_A, ϕ_A), (λ_B, ϕ_B), and (λ_P, ϕ_P), respectively.[3] Application of the cosine formula of spherical trigonometry to the 90° side, PA, of quadrantal triangle PCA (*v.* Fig. 2, §4, *post*), in which the angle at pole $C = \lambda_P - \lambda_A$, and the adjacent sides are $90° - \phi_P$, and $90° - \phi_A$, gives

$$\sin \phi_P \sin \phi_A + \cos \phi_P \cos \phi_A \cos (\lambda_P - \lambda_A) = 0, \tag{1}$$

or

$$\cos (\lambda_P - \lambda_A) = -\tan \phi_P \tan \phi_A. \tag{2}$$

Either (1) or (2) is the equation of the great circle passing thru points A and B, of north pole P; hence, if the coördinates (λ_0, ϕ_0) of *any other* point Q, when substituted for those of point A, satisfy either of these equations, point Q must lie on the great circle of which P is the north pole. The crux of the problem consists, then, in finding the coördinates of pole P.

3. *Determination of the Coördinates of Pole P: First Method.*—The coördinates of pole P can easily be found from those of the *north vertex* V (of coördinates λ_V, ϕ_V) of the great circle of which P is the north pole.[4] Vertex V lies either to the west of the 2 points, A and B, or between them, or to the east of them; if it lies to the west of them, the angle at point A in triangle ACB, in which the angle at pole $C = \lambda_B - \lambda_A$, and the adjacent sides are $90° - \phi_A$ and $90° - \phi_B$, is acute and that at point B is obtuse; if it lies between them, the angles at points A and B are both acute; and if it lies to the east of them, the angle at point A is obtuse and that at point B is acute (*v.* Fig. 1, in which 3 pairs of points,

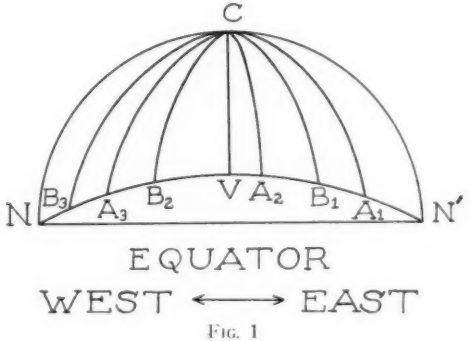

FIG. 1

A_i, B_i—$i = 1, 2, 3$—are represented). Evidently only one of the unknown angles in triangle ACB—*e.g.*, that at point B—need be found.

If g is an abstract positive quantity and G an auxiliary angle such that

$$g \sin G = \cos \phi_A \cos (\lambda_B - \lambda_A), \tag{3}$$

and

$$g \cos G = \sin \phi_A, \tag{4}$$

then

$$\tan G = \operatorname{ctn} \phi_A \cos (\lambda_B - \lambda_A); \tag{5}$$[5]

and it can be proved from the 3 fundamental formulas of spherical trigonometry that

$$\tan B = \tan (\lambda_B - \lambda_A) \sin G \sec (\phi_B + G). \tag{6}$$[6]

Application of the sine formula to side $CV = 90° - \phi_V$, in right triangle BCV, which is right-angled at vertex V and in which side $CB = 90° - \phi_B$, gives

$$\cos \phi_V = \cos \phi_B \sin B, \tag{7}$$[7]

from which ϕ_V can be evaluated.

In right triangle BCV, call angle BCV angle C'. Since the cosine of the hypotenuse of a spherical right triangle is equal to the product of the cotangents of the adjacent angles, it follows that

$$\text{ctn } C' = \sin \phi_B \tan (180° - B), \text{ or } \sin \phi_B \tan B, \tag{8}$$

in which $\tan (180° - B)$ is to be taken if the angle at point B in triangle ACB is obtuse—*i.e.*, if vertex V is west of point B—and $\tan B$, if the angle at point B is acute—*i.e.*, if vertex V is east of point B; hence,

$$\lambda_V = \lambda_B \pm C', \tag{9}$$

the plus sign in the right-hand member being used if vertex V is west, and the minus sign if it is east, of point B.

After the coördinates of vertex V have been determined from (7) and (9), those of pole P can be obtained at once from the obvious geometric relations

$$\lambda_P = 180° + \lambda_V, \tag{10}$$
$$\phi_P = 90° - \phi_V. \tag{11}$$[8]

4. *Determination of the Coördinates of Pole P: Second Method.*—The coördinates of pole P can be determined directly—*i.e.*, without first evaluating those of vertex V—in the following way.

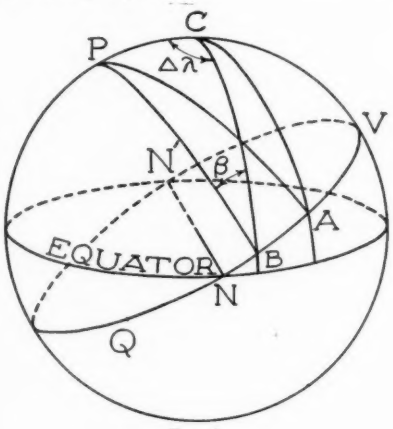

FIG. 2

In triangle ACB (Fig. 2), the angle at point B, which shall be called angle B, can be found from (6) of §3, *ante*. In quadrantal triangle BCP, 2 sides, $CB = 90° - \phi_B$ and $PB = 90°$, are known, and so is the included angle, *i.e.*, angle CBP, which shall be designated as angle β. Evidently angle $\beta = 90° -$ angle B, if angle B is acute—*i.e.*, if point B is west of vertex V—and angle $\beta =$ angle $B - 90°$, if angle B is obtuse—*i.e.*, if point B is east of vertex V. In triangle BCP,

side $CP = 90° - \phi_P$, and the angle at pole $C = \Delta\lambda$, the difference in longitude between pole P and point B. Application of the 3 fundamental formulas of spherical trigonometry to these unknown parts gives

$$\sin \phi_P = \cos \phi_B \cos \beta, \tag{12}$$

$$\cos \phi_P \cos \Delta\lambda = -\sin \phi_B \cos \beta, \tag{13}$$

and

$$\cos \phi_P \sin \Delta\lambda = \sin \beta, \tag{14}$$

from which

$$\tan \Delta\lambda = -\csc \phi_B \tan \beta, \tag{15}$$

and

$$\tan \phi_P = -\operatorname{ctn} \phi_B \cos \Delta\lambda = \cos \phi_B \operatorname{ctn} \beta \sin \Delta\lambda; \tag{16}$$

hence,

$$\lambda_P = \lambda_B \pm \Delta\lambda \tag{17}$$

—in which the upper (+) sign in the right-hand member is to be used if point B is west, and the lower (—) sign, if it is east, of vertex V—and ϕ_P is given by either (12) or (16), preferably by the middle member of (16).

5. *Determination of the Distance of a Given Point R from the Great Circle.*— If a given point R (of coördinates λ_R, ϕ_R) does *not* lie on the great circle passing thru points A and B, its distance from that great circle can, nevertheless, be readily found. Denote by S the point of intersection of the great circle thru pole P and

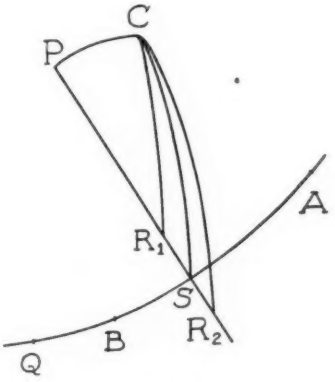

FIG. 3

point R, and the great circle thru points A and B (*v.* Fig. 3, in which point R is represented as being, first, at R_1—*i.e.*, at a distance from pole P *less* than 90°—and, second, at R_2—*i.e.*, at a distance from pole P *greater* than 90°). In triangle PCR, the angle at pole $C = \lambda_P - \lambda_R$,[9] and the adjacent sides are $90° - \phi_P$ and $90° - \phi_R$. Denote side PR, *i.e.*, that opposite the angle at pole C, by c; this side is equal evidently to the angular distance of point R from pole P. The length of c can be determined directly from the cosine formula, which gives

$$\cos c = \sin \phi_P \sin \phi_R + \cos \phi_P \cos \phi_R \cos (\lambda_P - \lambda_R), \tag{18}$$

or by the method employed in §3, *ante*.

Let h be an abstract positive quantity and H an auxiliary angle such that

$$h \sin H = \cos \phi_R \cos (\lambda_P - \lambda_R), \tag{19}$$

and

$$h \cos H = \sin \phi_R; \tag{20}$$

then

$$\tan H = \operatorname{ctn} \phi_R \cos (\lambda_P - \lambda_R), \tag{21}$$[10]

and it follows from the 3 fundamental formulas of spherical trigonometry that

$$\tan P = \tan (\lambda_P - \lambda_R) \sin H \sec (\phi_P + H), \tag{22}$$

and

$$\tan c = \operatorname{ctn} (\phi_P + H) \sec P, \tag{23}$$

in which angle P = angle CPR.

If the angular distance RS of point R from the great circle thru points A and B be denoted by d, then

$$d = 90^\circ - c, \text{ if } c < 90^\circ, \tag{24}$$

and

$$d = c - 90^\circ, \text{ if } c > 90^\circ. \tag{25}$$

If d be reduced to minutes of arc, the result will be equal to the *linear distance* of point R from the great circle thru points A and B, expressed in *nautical miles*.[11]

6. *Determination of the Coördinates of Point S.*—The coördinates (λ_S, ϕ_S) of point S—*i.e.*, the point on the great circle closest to the given point R—can easily be evaluated from quadrantal triangle PCS, in which 2 sides and the included angle are known, namely side $PS = 90^\circ$, side $CP = 90^\circ - \phi_P$, and angle CPS = angle P, which is determinable from (22) of §5, *ante*. Obviously, in triangle PCS, the angle at pole $C = \lambda_P - \lambda_S$,[12] and side $CS = 90^\circ - \phi_S$. Call angle CSP, angle S. Then it follows from the 3 fundamental formulas of spherical trigonometry as applied to the unknown elements, angle S, side $CS = 90^\circ - \phi_S$, and angle $C = \lambda_P - \lambda_S$, of the quadrantal triangle, that

$$\tan S = \operatorname{ctn} \phi_P \sin P, \tag{26}$$

$$\tan \phi_S = \operatorname{ctn} P \sin S, \tag{27}$$

and

$$\tan (\lambda_P - \lambda_S) = -\csc \phi_P \tan P, \tag{28}$$

from which the coördinates of point S, (λ_S, ϕ_S), readily ensue.

References and Notes

[1] In a paper entitled "The Great-Circle Distribution of the Tektites," *C.S.R.M.*, **2**, 28-34; *P. A.*, **46**, 224-30, 1938.

[2] If *either one* or *both* of the given points A and B be *south* of the equator, the *antipodal* point or points should be employed in the developments that follow, in order that *both* of the points utilized in the solution—which shall be called the "solutional points"—shall be *north* of the equator. If only *one* of the given (or original) points be south of the equator, the solutional points should still be so lettered that point A shall be the *more easterly* one.

[3] The geographic coördinates of a meteoritic fall can be obtained directly from its equatorial coördinate number (ECN); *v.* my "Catalog of Provisional Coördinate Numbers for the Meteoritic Falls of the World," *Univ. of New Mexico Publ. in Meteoritics*, No. 1, xiv + 54 pp., 1946.

[4] The *north vertex I'* of the great circle is the point on it nearest to the north geographic pole, C.

[5] The quadrant of angle G is evident from the signs of the right-hand members of (3) and (4).

[6] *Cf., e.g.,* W. W. Campbell's *The Elements of Practical Astronomy,* 2nd Ed., §10, p. 14, Macmillan, 1913, in which an analogous astronomical problem is worked out. The angular distance δ between points A and B can be computed from the formula:

$$\tan \delta = \operatorname{ctn} (\phi_B + G) \sec B, \tag{6a}$$

or directly from the cosine formula, which gives

$$\cos \delta = \sin \phi_A \sin \phi_B + \cos \phi_A \cos \phi_B \cos (\lambda_B - \lambda_A). \tag{6b}$$

[7] The angle at point B in right triangle BCV equals (1) the angle at point B in triangle ACB, if point B is west of vertex V, and (2) the *supplement* of the latter angle, if point B is east of vertex V (*v.* Fig. 1). It makes no difference in (7), however, whether the angle at point B in triangle ACB or the supplement of that angle is used, inasmuch as the sine of an angle is identically equal to that of its supplement.

[8] It is worth noting that $\phi_V = i$, the angle of inclination of the plane of the great circle passing thru points A and B to the plane of the Earth's equator (*i.e.,* the dihedral angle between those 2 planes), whereas the longitudes of the nodes of the great circle (*i.e.,* the points in which it intersects the equator, points N and N', in Figs. 1 and 2) are equal to $\lambda_V \pm 90°$.

[9] If pole P is west of point R; or $(\lambda_R - \lambda_P)$, if point R is west of pole P. In the latter case, λ_P and λ_R should be interchanged in (19), (21), and (22).

[10] *Cf.* n. ([5]), *ante.*

[11] 1 nautical mile, the length of 1′ on the Earth's surface, is equal approximately to 6,080 feet.

[12] If pole P is west of point R; or $(\lambda_S - \lambda_P)$, if point R is west of pole P. In the latter case, λ_P and λ_S should be interchanged in (28). Since point R is presumably not far from point S, their longitudes should not greatly differ; hence, in general, pole P is west—or east—of point S if it is west—or east—of point R. *Cf.* n. ([9]), *ante.*

A Possibly Meteoritic Dust-Cloud

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Abstract

This note contains a quoted account of an extraordinary observation made by Captain W. L. Stewart of the British Overseas Airways Corporation, on 1948 February 7, at $11^h 45^m$ U.T., while he was flying west-bound at an elevation of 10,000 feet, over a point whose equatorial coördinate number (ECN) = +0209,550, of what was apparently a downwardly concave, cylindrical dust-cloud with a length of nearly 60 miles, which may have been meteoritic in origin.

I have already called attention to the possibility that encounters between the Earth and such friable aerolites as the Norton-Furnas, Kansas-Nebraska, achondrites of 1948 February 18 might result in meteoritic falls from which "only dust would survive to reach the Earth."[1] The prodigious dust clouds left by the fall just referred to were certainly one of the most remarkable aspects of that greatest of all stone showers; and the even longer-enduring dust clouds that accompanied the Madrid, Spain, fall of 1896 February 10 (cl. = Chy,wv), constitute another pertinent example.

Recently, Dr. Carleton E. Buell of the Department of Mathematics & Astronomy of the University of New Mexico called to my attention an extraordinary observation made by Captain W. L. Stewart of the British Overseas Airways Corporation, on 1948 February 7, of what was apparently a downwardly concave,

cylindrical dust-cloud with a length of nearly 60 miles as shown on a sketch prepared by Stewart. Altho the cloud seen by Captain Stewart and his crew extended to considerably lower levels in the atmosphere than the *long-enduring* portion of the dust clouds formed by the Norton-Furnas fall, nevertheless, in many respects, Stewart's cloud closely resembled the initial form of the so-called "smoke trails" widely observed on 1948 February 18 in Kansas and Nebraska.

In the hope that additional observations of the cloud seen from the British Overseas Airways plane on 1948 February 7 may be reported to the Institute of Meteoritics by aviators or mariners who were near longitude W. 20° 55′, latitude N. 55° 03′, at $11^h 45^m$ U.T., on the date in question, I give below the complete observation of Captain Stewart as published in *Weather* (Royal Meteorological Society), **5**, No. 3, 110, March, 1950:

"An unusual atmospheric phenomenon was observed by Captain W. L. Stewart, of British Overseas Airways Corporation, when flying west-bound on an Atlantic flight. At 11:45 G.M.T., 7 February, 1948, his position was 55° 03′ N. and 20° 55′ W., and he was flying at 10,000 feet. At this time, an apparent condensation-trail was seen overhead against a blue sky.

"The accompanying sketch [omitted] has been prepared by Captain Stewart to illustrate the phenomenon. He has added that he would hesitate to estimate the height to which the east end of the trail was visible, but that it was certainly higher than indicated on the sketch [40,000 feet]. As the trail lay almost along the route, the aircraft, by a slight alteration in course, was flown underneath it for 25 minutes and then thru the lower end of the trail. The crew, by looking backwards and upwards from the top of the aircraft, could see into and along the trail. It appeared to be cylindrical, and about 300 to 400 feet in diameter at the level of flight. The diameter of the upper section must have been considerably larger, judging by the clarity with which it could be observed. The upper end of the trail was clearly defined, while the lower end was diffuse and disappeared at about 8,000 feet. The trail was white at all levels, altho the lower end was somewhat darker than the rest. It was well defined thruout the time it could be seen from the aircraft, and there appeared to be little or no tendency for diffusion except at the lower end. On altering [the] course to view it from the west, after passing the western end, it appeared in a straight line, disappearing into the eastern sky at great altitude, and in places appeared to be composed of spiral-shaped wisps.

"Captain Stewart reported 0.3 to 0.4 altostratus cloud, no high cloud, and unlimited visibility. The corrected temperature at flight level was —10°C. According to the upper-air charts at the Dorval Transatlantic Forecast Office, the upper winds were nearly constant in direction, and increased slowly in altitude. The directions, speeds, and temperatures were estimated as follows:

9,000 feet: 250°, 50 knots, — 8°C.
18,000 feet: 245°, 65 knots, —20°C.

"It has been suggested that the trail may have been caused by the passage of a meteor, in which case the cloud was most likely composed of dust or smoke particles left in its wake."

REFERENCE

[1] LaPaz, Lincoln, "The Achondritic Shower of February 18, 1948," *Publ. Astron. Soc. Pacific*, **61**, 63-73, 1949.

An Invitation to Members of the Society to Visit the Canyon Diablo, Arizona, Meteorite Crater*

Dr. John A. Russell, Secretary
The Meteoritical Society
Department of Astronomy
University of Southern California
Los Angeles 7, California

Dear Dr. Russell:

I shall be grateful if you will publish, to the membership of the Society, before its Flagstaff, Arizona, meeting, in September, 1950, the following statement:

"The Standard Iron Company, owner and developer of the Meteor Crater in Coconino County, Arizona, wishes to remind the members of the Society that they have a standing invitation to visit the Meteor Crater, as guests of the Standard Iron Company, at any time. This will be particularly true during the meeting of the Society in Flagstaff, Arizona, in September, 1950. It is hoped that members will avail themselves of this invitation, which, during the meeting, is meant to include their families as well.

"The Standard Iron Company is making every effort to promote the study of the Crater and of all the phenomena connected with it. The Company is equally eager to disseminate, as widely as possible, knowledge of the Crater, of the hypotheses concerning its origin, and of the details of its formation; and to give to every interested scholar the opportunity to study it to the fullest extent.

"The Standard Iron Company therefore welcomes any proposal for the advancement of knowledge about the Crater, or for particular research thereon. The right to excavate and to remove meteorites from the property must, of necessity, be an exclusive right, to avoid the complications and misunderstandings that would otherwise arise. This right is at present granted to the Institute of Meteoritics of the University of New Mexico, Albuquerque, and its permission will have to be obtained for any proposal to hunt, dig up, or remove, individual pieces of meteorite."

Yours truly,

D. Moreau Barringer, *President*,
Standard Iron Company,
1528 Walnut Street,
Philadelphia 2, Pennsylvania:
May 31, 1950

Graduate Work in Meteoritic Astronomy and Work on Meteoritic Dust in Canada

Under date of 1950 June 17, Dr. Frank S. Hogg, Director, David Dunlap Observatory, University of Toronto, Richmond Hill, Ontario, Canada, writes:

"Dear Professor Leonard:

"In the current [May] number of *P. A.* [**58**, 238-9, 1950], you refer to graduate students in meteoritic astronomy. At the University of Toronto, a graduate student, Mr. Donald K. Norris, took work in meteoritic astronomy in the years 1947-49, receiving his M.A. degree in June, 1949. His work, 'A Search for

*[The following letter has been received by the Secretary of the Society and is published with his permission.—Editor.]

Meteoritic Matter in Atmospheric Dust,' was presented at the Ottawa meeting of the American Astronomical Society and was summarized in *The Astronomical Journal* for September, 1949, p. 192. This work included a collecting expedition in Canada's sub-arctic.

"Mr. Norris was Gold Medallist in Geology in the honor course in geology and mineralogy at the University of Toronto, but he had worked several summers as an assistant at the David Dunlap Observatory. His graduate work in meteoritic astronomy was sponsored by a fellowship from the Ontario Research Council. He is now working on his Ph.D. degree in geology at the California Institute of Technology.

"While your discussion referred to priority in the United States, I thought that you would like to know of this Canadian record.

"Incidentally, you may be interested to learn that the Dunlap Observatory's work on meteoritic dust is this year being extended much farther into the Arctic. Another ex-student, Mr. John Galt, is doing work on terrestrial magnetism at Resolute Bay, as a staff member of the Dominion Observatory, Ottawa. As an additional activity, he is collecting dust samples with one of our collecting kits.

"Thru the coöperation of Mr. Andrew Thomson, Controller of the Meteorological Services of Canada, collections of dust at Baker Lake were made again last winter, by the meteorological staff. The results of these two simultaneous and widely separated collections, far from terrestrial contamination, should prove of interest."—F.C.L.

Final Notice of the 13th Meeting of the Society

Attention is called to the notice that appeared in *C.M.S., P.A.*, **58**, 303-4, June, 1950, concerning the 13th Meeting of the Society, which will be held at the Museum of Northern Arizona, Flagstaff, Arizona, and at the Canyon Diablo, Arizona, Meteorite Crater, on September 5, 6, and 7, 1950.

President of the Society: Arthur S. King, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: John A. Russell, Department of Astronomy, University of Southern California, Los Angeles 7, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

000451 *SS Cas.* A faint maximum occurred in the middle of May, when the variable reached about 10.8 magnitude. The previous maximum was more than a magnitude brighter.

020356 *UV Per.* Fernald observed a decrease from maximum early in March.

020657 *TZ Per.* This Z Cam-type star seems to be increasing its activity once again. It was near 12th magnitude the middle of February, and again in the middle of June.

060547 *SS Aur.* An 11th magnitude maximum was observed by many members in the middle of May, nearly 70 days after the previous maximum.

LIGHT CURVE OF Z CAMELOPARDALIS, 081473, 1938 1950.

063462 *RR Pic* (*Nova* 1925). Remains constant at 10.9 magnitude.

074922 *U Gem.* A maximum was observed between May 18 and 28.

080835 *CP Pup* (*Nova* 1942). Remains constant at 10.9 magnitude.

081473 *Z Cam.* The return of activity of Z Camelopardalis is shown in the accompanying light curve. The plotted points are one-day means, and cover the period from 1938 to 1950. During the times of activity, the variable has a mean period of about 20 days. It remains fairly constant, between magnitudes 11 and 12, from J.D. 2432640 to J.D. 2433300, and since then ranges from about 10.5 to a little fainter than 13th magnitude.

100661 *S Car.* This star has been unusually irregular during the last year, especially in the shape of light curve and the depth of minimum. The minimum early in June, 1949, was magnitude 6.8, in November it reached 7.8, and in April of this year it was down almost to the 10th magnitude. The most recent observations seem to indicate a standstill at 6.0, followed by a rise of half a magnitude the last of June.

150018 *RT Lib.* The maximum of magnitude 9.5 in the middle of May was about 1½ magnitudes fainter than the previous maximum the first of September.

152849 *R Nor.* This long, long-period variable is now on the decrease following its double maximum in September (8.5 mag.) and March (8.0 mag.) with a drop to 9.5 magnitude in December.

154428 *R CrB.* Remains fairly constant around 6th magnitude.

155823 *RZ Sco.* A maximum of 8.5 magnitude in the middle of May.

180445 *DQ Her* (*Nova* 1934). Varies irregularly between magnitudes 13 and 14.

180531 *T Her.* A bright maximum at 7.3 in the latter part of May, following a fainter one at 8.2 in December.

184300 *V603 Aql* (*Nova* 1918). Irregular variations between magnitudes 11 and 12.

191033 *RY Sgr.* This R CrB-type star still remains at maximum, between magnitudes 6 and 7.

193449 *R Cyg.* A very bright maximum. The variable was about 6.4 in the middle of June, about a month before the predicted time of maximum. Last year's maximum was about 8.5 magnitude.

194632 *Chi Cyg.* The minimum the first of May was very well observed, magnitude 13.4.

195109 *UU Aql.* A maximum was observed by Fernald the last of May.

195142 *RU Sgr.* A deep minimum near 14th magnitude. The last minimum in August was 12.5 magnitude.

195656 *RR Tel.* Remains constant at 8th magnitude.

213843 *SS Cyg.* Maximum Number 378 was observed during the last of June. Rosebrugh and Fernald caught it on the way up, and Welker, Bogard, Lankford, Peltier, and Webb observed it on the decrease.

224552 *Nova Lac* 1950. The nova is varying between magnitudes 10 and 11.

Suspected Variables Reported by AAVSO Observers

1. Greenley suspected variation in a star near 053068 S Cam. His observations confirm the variability suspected by Yendall nearly 50 years ago. The star is listed as number Zi 402 in the Zinner Catalogue of Suspected Variables, 1900

position: $5^h\ 32^m2$, $+68°\ 38'$. Greenley observed a variation from 9.5 to 10.7 magnitude, but not enough observations are available to determine any periodicity.

2. Buckstaff observed comparison star 11.9 on "d" chart of 162807 SS Her to be 10.4 magnitude on June 4. This is the first confirmation of variability suspected by Graff many years ago. The star is number Zi 1256 in the Zinner Catalogue, 1900 position: $16^h\ 28^m0$, $+7°\ 7'$.

3. Adams observed the comparison star 14.4 on "d" chart of 073723 S Gem to be magnitude 12.5 on May 22, 1950. More observations are needed on this interesting star.

Comet discovery. One of our members, Cleon Cain of Minneapolis, Minn., noticed a hazy object near Alpha Ophiuchi, a region very rich with nebulae, while he was observing on the night of May 21. He tried to look it up, but unfortunately had no complete list of nebulae available. Several days later, he received *Harvard Announcement Card* No. 1076, announcing the discovery of an 8th magnitude comet by Minkowski. Such is the sad life of an observer, to be so near a comet-discovery medal, and yet so far!

Observations received during May and June, 1950: A total of 7,803 observations—3,375 in May and 4,428 in June—was received from 60 observers, as follows:

Observer	May—1950—June No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	May—1950—June No. Var.	No. Ests.	No. Var.	No. Ests.
Adams	40	61	38	71	Lacchini	88	209	73	175
Ahnert, P.	30	144	35	356	Lankford	13	15	7	10
Ancarani	..	..	22	58	Leutenegger	19	69	30	263
Bappu, M. K.	..	..	27	37	LeVaux	51	54	29	32
Bicknell	10	94	19	52	Luft	..	..	7	18
Blunck	6	6	23	25	Lowder	14	15	..	..
Bogard	62	102	56	57	Mary	6	6	30	30
Buckstaff	7	7	15	20	Melville	1	1	1	2
Cain	20	26	2	2	Miller	5	5	6	6
Chandra	122	195	..	..	Morrisby	..	..	9	44
Charles	25	28	..	..	O'Byrne	11	22	..	..
Cilley	..	..	21	30	Oravec	80	153	49	95
Cooke	14	14	32	36	Parker	14	14	31	31
Cragg	..	..	24	30	Parks	..	..	15	15
Dafter	..	..	7	18	Pearcy	92	94	101	102
Darnell	2	8	1	9	Peltier	97	185	52	164
Diedrich, DeL.	2	5	2	7	Penhallow	34	42	41	76
Diedrich, G.	3	8	2	10	Peter	7	58	21	606
Dillon	7	13	7	11	Pierson	..	..	49	65
Drakakis	24	51	29	93	Renner	76	76	171	171
Estremadoyro, V. A.	8	12	14	25	Rosebrugh	15	33	12	41
Fernald	218	522	252	486	Sill	..	..	20	20
Ford	13	13	61	69	Snow	..	..	3	3
Galbraith	13	28	20	72	Stevens	11	18	..	..
Greenley	77	149	61	145	Taboada	67	72	36	36
Hartmann	101	105	73	75	Tifft	1	1	1	1
Herring	..	..	30	51	Toche	7	11	4	4
Holloway	..	..	18	20	Upjohn	..	..	35	35
Howarth	..	..	16	16	Upton	10	11	41	48
Jackson	3	4	..	..	Venter	19	27	12	26
Kato	20	49	17	35	Webb	..	..	15	16
Kelly, F. J.	11	12	10	10	Welker	5	5	19	19
Knowles	4	8	31	48	Yamada	25	53	32	100
de Kock	107	462	..	..	67 Totals	3,375		4,428	

Nova Search. Reports on the Nova Search Program were received during May and June from 9 observers, as follows:

Observer and Areas	MAY No. Nights	Mag.	JUNE Area	No. Nights	Mag.
Adams, 53, 54, 71, 72	1	7	39, 40	1	7
Adams, 53, 54	4	8	39, 40, 53, 54	1	8
Adams, 71, 72	6	8	53, 54	2	6
Adams, ...	...	...	71, 72	3	7
Adams, ...	...	...	71, 72	4	8
Blunck, ...	...	...	8, 9, 10	3	6
Diedrich, DeL., Dome	1	2	Dome	3	1
Diedrich, DeL., 94	5	3	94	1	3
Diedrich, DeL., 94	1	4	94	2	4
Diedrich, DeL., 94	2	5	94	2	5
Diedrich, DeL., 94	2	6	94	1	6
Diedrich, G., Dome	3	1	Dome	5	1
Diedrich, G., Dome	1	2	56	1	3
Diedrich, G., 56	3	4	56	3	4
Diedrich, G., 56	5	5	56	2	5
Diedrich, G., 56	2	6	56	3	6
Luft, ...	...	...	33, 34, 35	2	5
Rosebrugh, Dome	3	2	Dome	1	3
Smith, F. W., 3, 4	4	6	3, 4	4	6
Wells, K. A., ...	...	...	1-4; 8-10; 17-19; 57-60	1	6
Yamada, 57	3	6.5	57	10	6.5
Yamada, ...	...	...	57	2	7

July 18, 1950.

Comet Notes

By G. VAN BIESBROECK

COMET 1950 *b* (MINKOWSKI). The first new comet of this year was discovered by Minkowski at the Palomar Observatory on May 19. It was found on plates taken in the course of the National Geographic Society Sky Survey with the 48-inch Schmidt telescope. The first report gave this information:

1950 May 19.439 $18^h\ 16^m8 + 12°\ 3'$.

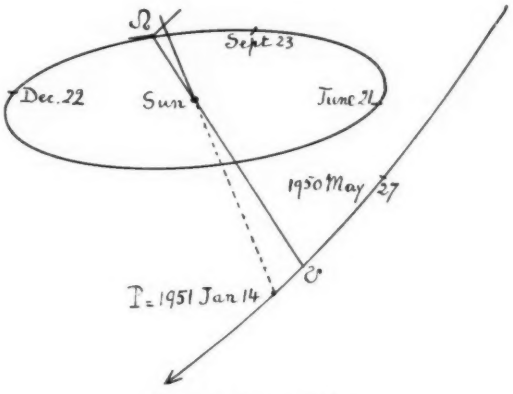
Magnitude 8. Diffuse object with a nucleus and a short tail. Daily motion $2^m\ 7^s$ west, 4′ south.

The motion was actually northward and since the announcement was delayed some observers failed at first to locate this relatively bright object. Most observers called the object fainter, of 10th or even 11th magnitude, but it is difficult to give a stellar magnitude to a diffuse object.

A first orbit was computed by L. E. Cunningham from observations from May 27 to June 6 at the Lick Observatory as follows:

Perihelion date	1951 Jan. 14.557
Node to perihelion	191°.870
Longitude of node	38.043
Inclination	144.211
Perihelion distance	2.5878 astr. units

It shows that the comet is very remote and will not change much in bright-



ORBIT OF COMET 1950 *b*.

ness for several months. The diagram indicates the relation of the comet's path to the earth's orbit around the sun. The line of nodes will be crossed in December after which the comet will remain below the ecliptic. Visibility will extend far into 1951 but be best for southern observers. The comet can be watched as an evening object with the help of the following ephemeris:

		α	δ	
		h m	° ′	Mag.
1950 Aug.	7	15 25.4	+ 3 42	10.4
	17	14.5	+ 1 41	
	27	6.5	— 0 17	
Sept.	6	15 1.0	— 2 09	10.3

After this date it will be lost in the twilight until the end of the year.

PERIODIC COMET D'ARREST follows closely its predicted course. It is now near maximum brightness. As recorded here this morning the nucleus was fairly well defined and nearly of 13th magnitude. It was surrounded by a round coma at least 3′ in diameter so that the total impression is that of an out-of-focus 11th magnitude star. The comet is slowly moving away from the morning sky and will come to opposition in November at which time it will however be fainter again.

PERIODIC COMET DANIEL, which was last seen in 1943, may be recovered before long in the morning sky. Perihelion occurs on August 24 but the comet is not expected to become brighter than 15th magnitude.

Williams Bay, Wisconsin, July 14, 1950.

General Notes

Dr. Otto Struve, well known throughout the world for his outstanding work in the development of astronomical research, has recently received two significant honors, first, by being elected a foreign member of the Amsterdam Academy of Sciences and Letters, and, second, by being awarded the decoration "Commandeur de l'Ordre de la Couronne" by the government of Belgium.

Dr. Newton L. Pierce, of Princeton, N. J. died suddenly on August 8. (This word came as we were going to press. Other details are not available to us.)

Dr. Frank Bradshaw Wood has resigned from the faculty of the University of Arizona to become executive director of the observatories of the University of Pennsylvania.

Dr. John C. Duncan retired as Professor of Astronomy in Wellesley College and Director of the Whitin Observatory on June 30, after occupying that position for 34 years. In the academic year 1950-51, he will be Visiting Professor of Astronomy in the University of Arizona and Visiting Astronomer in the Steward Observatory.

Dr. Edward A. Fath, a member of the faculty of Carleton College for the past thirty years, retired from active service on June 30, 1950. From 1926 until his retirement, Dr. Fath was Director of Goodsell Observatory and chairman of the Department of Astronomy. During this period Dr. Fath was also connected with the publication of POPULAR ASTRONOMY, part of the time as associate editor and part of the time as a member of the board of collaborators. At the Carleton College commencement on June 11, the honorary degree of Doctor of Science was conferred upon him. Dr. and Mrs. Fath left Northfield in July with the expectation of making their future home in California.

Dr. Leendert Binnendijk, recently from Swarthmore College, will be the new Director of the Goodsell Observatory, and associate professor of astronomy. Beginning with the new college year, the departments of astronomy and mathematics will be combined under one chairmanship.

Galle Correspondence for Sale

The descendants of J. G. Galle, the discoverer of the planet Neptune in 1846, are in possession of some 95 letters written to Galle by Alexander von Humboldt. These letters are now for sale. Any one interested may obtain further information concerning these letters by addressing an inquiry to Professor W. Becker, Hamberg-Bergedorf Observatory, Hamburg, Germany.

Mt. Wilson and Palomar Astronomers Honored

Honorary Doctor of Philosophy degrees have been conferred upon two members of the Mt. Wilson and Palomar Observatories staff by the University of Lund, Sweden, it was announced on June 23, 1950. The degrees, officially designated as Ph.D. Honoris Causa, were awarded Dr. Ira S. Bowen, Director of the combined observatories, and Milton Humason, astronomer and authority on measuring of spectra. The University of Lund faculty, in announcing the award, cited Dr. Humason for his contributions to astronomical research and particularly in measuring of the spectra and radial velocities of far distant galaxies, which measuring "demanded magnificent observation work." Dr. Bowen's citation was for his contributions in both atomic and astrophysics research, his interpretation of spectra of nebulae and the fact that he directs the two largest observatories in the world.

Provisional Sunspot Numbers for May, 1950*

1	144	11	101	21	92
2	146	12	71	22	112
3	111	13	69	23	128
4	106	14	60	24	162
5	129	15	47	25	142
6	139	16	57	26	134
7	130	17	61	27	131
8	121	18	79	28	121
9	108	19	86	29	109
10	105	20	89	30	86
				31	72

Mean 104.8

Provisional Sunspot Numbers for June, 1950*

1	72	11	102	21	55
2	84	12	72	22	86
3	84	13	95	23	107
4	66	14	101	24	108
5	58	15	94	25	128
6	54	16	84	26	113
7	50	17	83	27	97
8	70	18	80	28	74
9	65	19	80	29	82
10	108	20	66	30	78

Mean 83.2

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Book Reviews

Astronomy Charted, by Ralph A. Wright, 4 Mason Street, Worcester, Massachusetts. $3.00.

The above title is given to a series of charts, twenty-five in number, each 8½ by 11 inches, with holes punched for filing in a loose leaf folder. Each chart discusses with diagrams and description a topic related directly or indirectly to astronomical study. Typical topics are: The Earthquake Speaks; Subterranean Astronomy; Into the Great Unknown Overhead; Atomic Microseisms; Radar for Astronomy; Seven Eclipses in One Year. Each topic is discussed briefly and succinctly. The charts enliven and elucidate the descriptions and *vice versa.* A study of these charts cannot help but clarify the reader's conception of the items presented. C.H.G.

Untersuchungen des Lichtwechsels von 70 unperiodischen Veränderlichen, by Max Beyer. (Investigations on the change of light of 70 non-periodic variables), *Astronomische Abhandlungen,* Supplement to *Astronomische Nachrichten,* vol. 12, no. 2, Berlin: Akademie-Verlag, 1950 [74 pp., 1 ill.; price 9 DM].

This treatise contains the results of the author's own observations of the years 1923-1940; this work is an immediate continuation and supplementation of the previously published treatise "Über den Lichtwechsel der Veränderlichen mit Perioden von 30 bis 150 Tagen" (On the variation of light of variables with periods of 30-150 days.) Continued attention and photometric observation furnish the only possibility for an explanation of the laws of their light-variation and of the physical causes of the latter. In the case of the non-periodic variables dis-

cussed in the present work, a detailed presentation of the original observations is essential in order to place the entire material—in the interest of further research—at the disposal of all investigators active in this field. The author, who has devoted decades to these studies, enjoys international reputation.

Out of My Later Years, by Albert Einstein. (The Philosophical Library, Inc., 15 E. 40th St., New York 16, N. Y. $4.75.)

This second collection of the author's essays comprises those articles, comments, and observations written during the past sixteen years. Classified under the heading: Convictions and Belief, Science, Public Affairs, Science and Life, Personalities, and My People, they prove that the greatest scientist of our time is yet a human being of varied interests and wide sympathies, whose emotional and spiritual impulses are by no means dominated by rationalistic thought. Nor are the values most important to him merely those embodied in physical existence and in observable phenomena.

The fragmentary, unconnected nature of these papers is informed by an underlying unity of spirit revealed in a style at once lucid and imaginative—a spirit of philosophical serenity implicit in his approach and attitude even when he is discussing doubtful issues. In matters of scientific explanation, such as the exposition in simplest terms for the layman, is reflected the authority of the mathematical genius, but no less discerning is his interpretation of social, political, and personal problems.

"I live in that solitude which is painful in youth," he says, "but delicious in the years of maturity," for it is only then that one becomes aware of the significance of existence and can see its events in their true perspective. Yet "knowledge of truth alone does not suffice," for "it resembles a statue of marble which stands in the desert and is continuously threatened with burial by the shifting sand. The hands of service must ever be at work, in order that the marble continue lastingly to shine in the sun. . . The aim (of education) must be the training of . . . individuals who see in this service their highest life problem."

Although averse to pacificism as a means of attaining peace, Mr. Einstein is also opposed to the militarization of this country, because it will "surely destroy the democratic spirit and the dignity of the individual. . . There is only one path to peace and security: the path of supra-national organization." For the structure and administration of such an institution, he provides concrete suggestion.

The section entitled "Personalities" is really misleading. In nine short comments, five of which were written "in memoriam," he defines and extols the accomplishments of Isaac Newton, Gandhi, Marie Curie, and other important figures. More appealing, because more deeply sympathetic, are the essays concerning "My People," with their consideration of the Jewish problem. "Why are the Jews hated?" he asks, and proceeds to discuss the historical as well as the psychological sources of anti-Semitism as manifested in acts of violence, oppression, and segregation. The systematic destruction of the Jews in Europe during the last war, and the settlement in Palestine are also dealt with, and the reader is impressed by the miracle achieved in the creation of the community in Israel. Even here, however, he retains his judicial and balanced attitude of appraisal. The value of the entire section, indeed, is the sense we have of its complete justice.

Ruth F. Eliot.

Carleton College, Northfield, Minnesota.

Biography of the Earth, by George Gamow. (A Pelican Mentor Book, published by The New American Library. 192 pages, 35 cents.)

A review copy of this small volume, issued late in 1947, has recently reached our desk. The title arrests the attention, and, for those who know, the interest is heightened by the name of the author. This small-sized volume is packed with information. The descriptions are frequently supplemented and made clearer by illustrations. The time interval presented is enormous. Roughly speaking the earth came into being some two billion years ago. It, along with the sun, may reach some kind of a destiny some ten to twenty-five billion years hence. Sometime in this interval the moon became separated from the earth and sometime it may return and again be merged with the earth. In the nature of the case, these long-range questions must to some extent be speculations, but many currently accepted conditions related to the earth are well attested by scientific investigations.

An index to the volume is included, an unusual but very useful feature.

C.H.G.

Reflections of a Physicist, by P. W. Bridgman. ix plus 392 pp., 1950. (Philosophical Library, Inc., 15 E. 40th St., New York. $5.00.)

This book is a collection of Bridgman's non-technical writings. The chapters dealing with his Theory of Operational Analysis are essentially technical methodology, but even here his style carries the reader along at a pleasant pace, for the book is eminently readable.

I should hold that the theme of the book is that the present goal of mankind should be a free society operating under the guidance of *intelligence* (which is never defined, yet seems to imply a maximum of scientific method). The man of science must be free to discover for himself whatever he can without the tremulous reins of government or any special group pulling at him whenever anyone becomes suspicious that some old idea is likely to be replaced by a new one. This does not mean that there is to be no check on the scientist as citizen. When the free scientist verifies his hypotheses (ideas) they may be accepted as true; if he cannot verify them, they will be rejected as false. The scientist more than any other professional is subject to devastating criticism from his free colleagues. Whenever the uninformed layman, however, pretends to be able to know *a priori* what the free scientist cannot or ought not do in conducting investigation, then the scientist becomes an instrument for some special pressure group and hence is no longer free, and no longer a scientist.

The most interesting section of the book deals with Bridgman's Theory of Operational Analysis. His formulation of this was first done in "The Logic of Modern Physics" in 1928. As a result of criticism, he has found it necessary to qualify his original formulation of the theory. He no longer holds "that meanings are *synonymous with operations.*" His newer formulation of what he means by knowing the meanings of a term is that "I must know the conditions under which I would use the term, and conversely, to know the meaning of a term which my fellow uses, I must be able to reconstruct the conditions attendant on the use of the term by him. Analysis of the conditions attendant on the use of the term is an analysis of operations. From this point of view, *meanings are operational.*" He cautions that he does not mean by this that a meaning is *nothing but* an operation, but that knowing certain operations is a "necessary as distinguished from a sufficient characterization, in the sense of the mathematician." The Preface contains a more recent statement: "The essence of the attitude is that the mean-

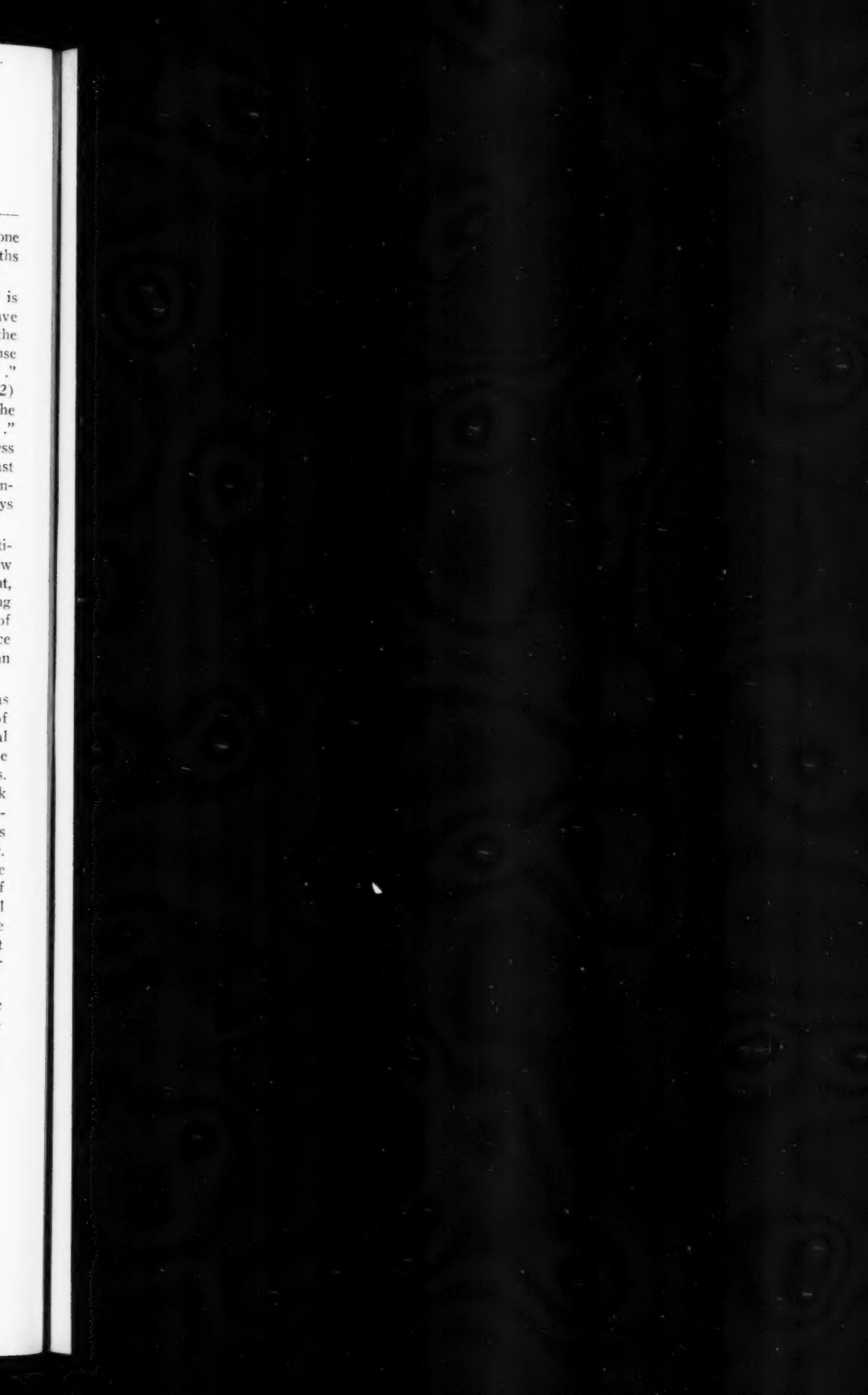
ings of one's terms are to be found by an analysis of the operations which one performs in applying the term in concrete situations or in verifying the truths of statements or in finding the answers to questions."

Bridgman holds in Chapter 2 that "definitions *must* be operational and it is tautological to speak of operational definitions." Hypothetical operations have their meanings "in terms of a program of actual operations. . ." Concerning the paradoxes of the infinite in mathematics, he says, these "arise precisely because in mathematics infinity is sometimes defined in terms of impossible operations. . ." The values of operational definitions are: (1) that they increase precision, (2) that they expose underlying operations, and (3) that they insure against the development of the "'same' construct defined by two independent operations. . ." One must be cautious, however, of attempting to use operational definitions "unless the situations to which they are applied are sufficiently developed so that at least two methods are known of getting to the terminus." The last statement is essentially an answer to his critics who have said that operationalism is not always applicable.

Group II of the book is of considerable historical interest. It shows the attitude of the scrupulous and, at the same time, imaginative physicist toward new developments in physics. Whereas some prominent, and many not so prominent, physicists made unwarranted extrapolations in cosmogony and cosmology following the development of relativity theory, quantum mechanics, and the second law of thermodynamics, it is clear that Bridgman seldom went further than the evidence allowed. It is conceivable that a logical empiricist might hold that even Bridgman went distressingly far.

The last group of essays entitled "Primarily Social" is not as satisfactory as the earlier essays. Here he attempts, with obviously insufficient knowledge of economics and political philosophy, to suggest naive or outworn solutions to social problems. There is a curious plea in Chapter 19 for more inefficiency in the United States in its rôle of world economic advisor and distributor of goods. Here Bridgman condones a form of Gandhiism which seriously reflects his lack of knowledge in economics. More important is his concern with governmental encroachments on scientific research in universities. He has no proposal, besides pious hopes, as to how sufficient funds are to be raised without federal subsidy. Chapter 20 is entitled "Sentimental Democracy and the Forgotten Physicist." He states in this that there is a "sinister" deterioration going on in this country "of the admiration and respect with which the community holds the man of unusual intellectual ability." He has produced no evidence for this, presumably because it is self-evident. He believes that mediocrity is *now* (1949) in the saddle, that the superior rich are being taxed to support the inferior lazy (poor). I am rather surprised that this has not been reprinted in *The Reader's Digest*.

The last two chapters of the book are discussions of the rôle of intelligence in the modern world. There is little here that is not said better by Dewey, Whitehead, or Russell. Intelligence is required not only in physical science, but in social science. The way to get our social thinking to catch up to our physical thinking is through application of intelligence. This means a clean break with absolutes, transcendentals, and occult hangovers from a prescientific era. We cannot operate with a 20th century mind in physics and an 11th century mind in ethics and social philosophy. Intelligence is not only our last, it is our *only* hope.

DALE RIEPE.

Dept. of Philosophy, Carleton College, June 15, 1950.